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ANNUAL REPORT OF THE
BOARD OF REGENTS OF
THE SMITHSONIAN
INSTITUTION

SHOWING THE
OPERATIONS, EXPENDITURES, AND
CONDITION OF THE INSTITUTION
FOR THE YEAR ENDING JUNE 30

1923



(Publication 2758)

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THE SMITHSONIAN INSTITUTION

OPERATIONS, ESTABLISHMENTS AND
CONDITION OF THE INSTITUTION
FOR THE YEAR ENDING 1953

1953



WASHINGTON, D.C.

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Washington, D.C.

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LETTER

FROM THE

ACTING SECRETARY OF THE SMITHSONIAN INSTITUTION

SUBMITTING

THE ANNUAL REPORT OF THE BOARD OF REGENTS OF THE
INSTITUTION FOR THE YEAR ENDING JUNE 30, 1923

SMITHSONIAN INSTITUTION,
Washington, June 21, 1924.

To the Congress of the United States:

In accordance with section 5593 of the Revised Statutes of the United States, I have the honor, in behalf of the Board of Regents, to submit to Congress the annual report of the operations, expenditures, and condition of the Smithsonian Institution for the year ending June 30, 1923. I have the honor to be,

Very respectfully, your obedient servant,

C. G. ABBOT,
Acting Secretary.

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ANNUAL REPORT OF THE BOARD OF REGENTS OF THE SMITHSONIAN
INSTITUTION FOR THE YEAR ENDING JUNE 30, 1923

SUBJECTS

1. Annual report of the secretary, giving an account of the operations and condition of the Institution for the year ending June 30, 1923, with statistics of exchanges, etc.

2. Report of the executive committee of the Board of Regents, exhibiting the financial affairs of the Institution, including a statement of the Smithsonian fund, and receipts and expenditures for the year ending June 30, 1923.

3. Proceedings of the Board of Regents for the fiscal year ending June 30, 1923.

4. General appendix, comprising a selection of miscellaneous memoirs of interest to collaborators and correspondents of the Institution, teachers, and others engaged in the promotion of knowledge. These memoirs relate chiefly to the calendar year 1923.

IX

THE SMITHSONIAN INSTITUTION

June 30, 1923

Presiding officer ex officio.—WARREN G. HARDING, President of the United States.

Chancellor.—CALVIN COOLIDGE, Vice President of the United States.

Members of the Institution:

WARREN G. HARDING, President of the United States.

CALVIN COOLIDGE, Vice President of the United States.

WILLIAM HOWARD TAFT, Chief Justice of the United States.

CHARLES EVANS HUGHES, Secretary of State.

ANDREW W. MELLON, Secretary of the Treasury.

JOHN WINGATE WEEKS, Secretary of War.

HARRY M. DAUGHERTY, Attorney General.

HARRY S. NEW, Postmaster General.

EDWIN DENBY, Secretary of the Navy.

HUBERT WORK, Secretary of the Interior.

HENRY CANTWELL WALLACE, Secretary of Agriculture.

HERBERT CLARK HOOVER, Secretary of Commerce.

JAMES JOHN DAVIS, Secretary of Labor.

Regents of the Institution:

CALVIN COOLIDGE, Vice President of the United States, Chancellor.

WILLIAM HOWARD TAFT, Chief Justice of the United States.

HENRY CABOT LODGE, Member of the Senate.

A. OWSLEY STANLEY, Member of the Senate.

MEDILL MCCORMICK, Member of the Senate.

ALBERT JOHNSON, Member of the House of Representatives.

R. WALTON MOORE, Member of the House of Representatives.

GEORGE GRAY, citizen of Delaware.

CHARLES F. CHOATE, Jr., citizen of Massachusetts.

HENRY WHITE, citizen of Washington, D. C.

ROBERT S. BROOKINGS, citizen of Missouri.

IRWIN B. LAUGHLIN, citizen of Pennsylvania.

FREDERICK A. DELANO, citizen of Washington, D. C.

Executive committee.—GEORGE GRAY, HENRY WHITE, FREDERIC A. DELANO.

Secretary of the Institution.—CHARLES D. WALCOTT.

Assistant Secretary.—C. G. ABBOT.

Chief Clerk.—HARRY W. DORSEY.

Accounting and disbursing agent.—W. I. ADAMS.

Editor.—W. P. TRUE.

Assistant librarian.—PAUL BROCKETT.

Property clerk.—J. H. HILL.

THE NATIONAL MUSEUM

Keeper ex officio.—CHARLES D. WALCOTT, Secretary of the Smithsonian Institution.

Administrative assistant to the Secretary, in charge.—W. DE C. RAVENEL.

Head curators.—WALTER HOUGH, LEONARD STEJNEGER, GEORGE P. MERRILL.

Curators.—PAUL BARTSCH, R. S. BASSLER, T. T. BELOTE, AUSTIN H. CLARK, F. W. CLARKE, F. V. COVILLE, W. H. DALL, C. W. GILMORE, WALTER HOUGH, L. O. HOWARD, ALEŠ HRDLÍČKA, NEIL M. JUDD, FREDERICK L. LEWTON, GEORGE P. MERRILL, GERRIT S. MILLER, JR., CARL W. MITMAN, ROBERT RIDGWAY, WALDO L. SCHMITT, LEONHARD STEJNEGER.

Associate curators.—J. M. ALDRICH, W. R. MAXON, C. E. RESSER, CHARLES W. RICHMOND, J. N. ROSE, P. C. STANDLEY, DAVID WHITE.

Chief of correspondence and documents.—H. S. BRYANT.

Disbursing agent.—W. I. ADAMS.

Superintendent of buildings and labor.—J. S. GOLDSMITH.

Editor.—MARCUS BENJAMIN.

Assistant librarian.—N. P. SCUDDER.

Photographer.—ARTHUR J. OLMSTED.

Property clerk.—W. A. KNOWLES.

Engineer.—C. R. DENMARK.

Shipper.—L. E. PERRY.

NATIONAL GALLERY OF ART

Director.—WILLIAM H. HOLMES.

FREER GALLERY OF ART

Curator.—JOHN ELLERTON LODGE.

Associate curator.—CARL WHITING BISHOP.

Assistant curator.—GRACE DUNHAM GUEST.

Associate.—KATHARINE NASH RHOADES.

Superintendent.—JOHN BUNDY.

BUREAU OF AMERICAN ETHNOLOGY

Chief.—J. WALTER FEWKES.

Ethnologists.—JOHN P. HARRINGTON, J. N. B. HEWITT, FRANCIS LA FLESCHÉ, TRUMAN MICHELSON, JOHN R. SWANTON.

Editor.—STANLEY SEARLES.

Librarian.—ELLA LEARY.

Illustrator.—DE LANCEY GILL.

INTERNATIONAL EXCHANGES

Chief Clerk.—C. W. SHOEMAKER.

NATIONAL ZOOLOGICAL PARK

Superintendent.—NED HOLLISTER.

Assistant Superintendent.—A. B. BAKER.

ASTROPHYSICAL OBSERVATORY

Director.—C. G. ABBOT.

Aid.—F. E. FOWLE, JR.

Assistant.—L. B. ALDRICH.

REGIONAL BUREAU FOR THE UNITED STATES, INTERNATIONAL
CATALOGUE OF SCIENTIFIC LITERATURE

Assistant in charge.—LEONARD C. GUNNELL.

REPORT
OF THE
SECRETARY OF THE SMITHSONIAN INSTITUTION

CHARLES D. WALCOTT

FOR THE YEAR ENDING JUNE 30, 1923

To the Board of Regents of the Smithsonian Institution:

GENTLEMEN: I have the honor to submit herewith the customary annual report showing the activities and condition of the Smithsonian Institution and its branches during the fiscal year ending June 30, 1923. The first 26 pages of the report contain an account of the affairs of the Institution proper, with brief abstracts of the work carried on by the various branches of the Institution, while Appendixes 1 to 10 give more detailed reports of the operations of the United States National Museum, the National Gallery of Art, the Freer Gallery of Art, the Bureau of American Ethnology, the International Exchanges, the National Zoological Park, the Astrophysical Observatory, the United States Regional Bureau of the International Catalogue of Scientific Literature, the Smithsonian Library, and of the publications of the Institution and its branches.

THE SMITHSONIAN INSTITUTION

THE ESTABLISHMENT

The Smithsonian Institution was created by act of Congress in 1846, according to the terms of the will of James Smithson, of England, who in 1826 bequeathed his property to the United States of America "to found at Washington, under the name of the Smithsonian Institution, an establishment for the increase and diffusion of knowledge among men." In receiving the property and accepting the trust Congress determined that the Federal Government was without authority to administer the trust directly, and therefore constituted an "establishment" whose statutory members are "the President, the Vice President, the Chief Justice, and the heads of the executive departments."

THE BOARD OF REGENTS

The affairs of the Institution are administered by a Board of Regents whose membership consists of "the Vice President, the Chief Justice, three Members of the Senate, and three Members of the House of Representatives, together with six other persons other than Members of Congress, two of whom shall be resident in the City of Washington and the other four shall be inhabitants of some State, but no two of them of the same State." One of the Regents is elected chancellor by the board; in the past the selection has fallen upon the Vice President or the Chief Justice; and a suitable person is chosen by them as secretary of the Institution, who is also secretary of the Board of Regents and the executive officer directly in charge of the Institution's activities.

In regard to the personnel of the board, the following changes occurred during the year: Robert Walton Moore, Member of the House of Representatives from Virginia, was appointed a Regent by the Speaker of the House, to succeed the late Lemuel P. Padgett. Mr. Henry White was reappointed by joint resolution of Congress, Mr. Irwin B. Laughlin, of Pennsylvania, was appointed to succeed the late Dr. A. Graham Bell, and Mr. Frederic A. Delano, of the District of Columbia, to succeed Mr. John B. Henderson, who died during the year. The election of Representative Frank L. Greene to the Senate on March 4, 1923, automatically terminated his term as a Regent.

The roll of Regents at the close of the fiscal year was as follows: Calvin Coolidge, Vice President of the United States, Chancellor; William H. Taft, Chief Justice of the United States; Henry Cabot Lodge, Member of the Senate; A. Owsley Stanley, Member of the Senate; Medill McCormick, Member of the Senate; Albert Johnson, Member of the House of Representatives; R. Walton Moore, Member of the House of Representatives; George Gray, citizen of Delaware; Charles F. Choate, jr., citizen of Massachusetts; Henry White, citizen of Washington, D. C.; Robert S. Brookings, citizen of Missouri; Irwin B. Laughlin, citizen of Pennsylvania; and Frederic A. Delano, citizen of the District of Columbia.

GENERAL CONSIDERATIONS

A systematic campaign was begun during the year to increase the endowment of the Institution to more adequate proportions though at the close of the year this has had no material success. It is felt that there is considerable misunderstanding throughout the country regarding the resources of the Smithsonian Institution, many persons believing that it is supported, at least to some extent, by the Government. As a matter of fact, though the Congress appropriates funds annually for the maintenance of the various bureaus which

have grown up around the Institution and are administered by it, not one cent from these appropriations can be used by the Institution proper for the purpose for which it was created, "the increase and diffusion of knowledge among men."

These purposes, which are carried out through research, exploration, and publication, must be supported by the funds of the Institution itself or by money contributed for special purposes by the friends of the Institution. As the endowed funds of the Institution, consisting of the original bequest to the Nation of James Smithson and subsequent gifts and bequests, amount to only a little over a million dollars, yielding an available annual income of approximately \$60,000 from which the administrative costs of the Institution and of the general direction of its seven branches must be paid, it will be readily apparent that but little remains each year for research and exploration. It is believed that if the financial situation of the Smithsonian Institution and its excellent position for carrying on needed scientific work were more fully understood, there would be ready response to its plea for a larger endowment, and its program of scientific research and exploration could then be expanded and pushed vigorously, to the ultimate benefit of mankind.

An outstanding event of the year was the formal opening on May 2, 1923, of the Freer Gallery of Art, the culmination of Mr. Charles L. Freer's splendid gift to the Nation, through the Smithsonian Institution, of his unrivalled collections of American and Oriental art and a beautiful building to house them. The opening was well attended and was the cause of favorable comment in art circles throughout the country, many of the leading art journals carrying full accounts of the gallery and its contents. The building is now open to the public daily except Mondays.

FINANCES

The permanent investments of the Institution consist of the following:

Deposited in the Treasury of the United States.....	\$1, 000, 000
---	---------------

CONSOLIDATED FUND

Miscellaneous securities carried at cost of \$192,770.28, either purchased or acquired by gift, and constituting the consolidated fund, namely:

West Shore Railroad Co. guaranteed 4 per cent first-mortgage bonds, due in 2361.....	\$42, 000
Cleveland Electric Illuminating Co. first-mortgage 5 per cent gold bonds, due in 1939.....	10, 000
Atchison, Topeka & Santa Fe Railway Co. 4 per cent general mortgage bonds, due in 1995, gift.....	2, 000
Chesapeake & Ohio Railroad Co. first consolidated mortgage 5 per cent bonds, due in 1939, gift.....	2, 000
Baltimore & Ohio Railroad Co. 5 per cent refunding general mortgage bonds, due in 1995, gift.....	5, 000

CONSOLIDATED FUND—continued

P. Lorillard Co. 7 per cent gold bonds, due in 1944, gift.....	\$6, 000
Liggett & Myers Tobacco Co. 7 per cent gold bonds, due in 1944, gift..	6, 000
New York Central & Hudson River Railroad Co. 4 per cent gold debenture bonds, due in 1934.....	4, 000
Dominion of Canada 5 per cent gold bonds, due May 1, 1952.....	5, 000
Province of Ontario debenture bonds, due in 1952.....	3, 000
Norman P. Scala 3-year note on 140 East Capitol Street, due November 20, 1925, at 6 per cent.....	4, 000
Northern Pacific Railway Co. refunding and improvement 5 per cent bonds, due 2047.....	6, 000
Real estate 7 per cent trust notes on improved property in the District of Columbia, due 1925.....	5, 000
Northern Pacific Railway Co. 6 per cent bonds, due 2047.....	41, 500
New York Central Railroad Co. refunding and improvement 5 per cent bonds, due in 2013.....	10, 000
Brooklyn Rapid Transit Co. 5 per cent secured gold notes (in course of adjustment) ¹	3, 500
United States first Liberty loan.....	200
United States second Liberty loan.....	100
United States third Liberty loan.....	10, 150
United States fourth Liberty loan.....	50
Achison, Topeka & Santa Fe Railway Co. 5 per cent preferred stock, gift.....	125
American Smelting & Refining Co. 7 per cent preferred stock, gift.....	60
Baltimore & Ohio Railroad Co. 4 per cent preferred stock, gift.....	125
California Electric Generating Co. 6 per cent preferred stock, gift.....	100
Electric Bond & Share Co. 6 per cent preferred stock, gift.....	20

The sums invested for each specific fund or securities acquired by gift are described as follows:

Fund	United States Treasury	Consolidated fund	Total
Avery fund.....	\$14, 000. 00	\$27, 689. 80	\$41, 689. 80
Virginia Purdy Bacon fund.....		48, 300. 00	48, 300. 00
Lucy H. Baird fund.....		1, 285. 58	1, 285. 58
Chamberlain fund.....		35, 000. 00	35, 000. 00
Habel fund.....	500. 00		500. 00
Hamilton fund.....	2, 500. 00	500. 00	3, 000. 00
Caroline Henry fund.....		1, 023. 00	1, 023. 00
Hodgkins general fund.....	116, 000. 00	37, 275. 00	153, 275. 00
Hodgkins specific fund.....	100, 000. 00		100, 000. 00
Bruce Hughes fund.....		11, 194. 76	11, 194. 76
Morris Loeb fund.....		2, 390. 00	2, 390. 00
Lucy T. and George W. Poore fund.....	26, 670. 00	10, 055. 00	36, 725. 00
Addison T. Reid fund.....	11, 000. 00	4, 419. 00	15, 419. 00
Rhees fund.....	590. 00	238. 00	828. 00
George K. Sanford fund.....	1, 100. 00	451. 00	1, 551. 00
Smithson fund.....	727, 640. 00	1, 429. 14	729, 069. 14
Charles D. and Mary Vaux Walcott research fund.....		11, 520. 00	11, 520. 00
Total.....	1, 000, 000. 00	192, 770. 28	1, 192, 770. 28

¹ Terms have been agreed upon for reconverting the notes of the Brooklyn Rapid Transit Co., and it is expected that the conversion will be made very soon.

Mr. B. H. Swales, honorary assistant curator, division of birds, has continued his contributions during the past year for the purchase of specimens for the division of birds. This year his contributions have amounted to \$400.

Dr. William L. Abbott has contributed \$4,000 during the past year for the purpose of continuing his researches in natural history and the collection of specimens in China. With the unexpended sum of \$3,173.58, the balance remaining from the work in Australia, the total sum available for work in China has amounted to \$7,173.58.

The Institution is indebted to Mr. John A. Roebling for a further contribution of \$28,288.19 toward continuing researches in astrophysics by aiding the solar observing stations in Chile and the United States, and providing for publication of scientific papers, and for making meteorological investigations elsewhere.

Freer Gallery of Art.—A stock dividend of 100 per cent was declared by Parke, Davis & Co., as of record of December 18, 1922, which gives the Smithsonian Institution a total number of shares of the stock of that company aggregating 40,930, making a total for each classification as follows:

	Shares
Curator's fund, Freer Gallery of Art.....	3, 484
Court and grounds fund, Freer Gallery of Art.....	3, 484
Court and grounds, maintenance fund, Freer Gallery of Art.....	870
Residuary legacy, Freer Gallery of Art.....	33, 092

The Institution, as residuary legatee, also holds the following securities, acquired in settlement of the Freer estate:

Detroit Country Club, first mortgage 5 per cent bond, due January 1, 1931	\$1, 000
University Club, Detroit, first mortgage 5 per cent bonds, due 1923 and 1924	2, 000
Great Lakes Engineering Works, first mortgage, 7 per cent bonds, due in 1928, 1929, and 1930	20, 000

In my last report, I mentioned a loan which the Institution was compelled to make for the purpose of paying certain taxes. The loan has been paid during the year. The building fund is now exhausted.

The practice of depositing on time, in local trust companies, such revenues as may be spared temporarily has been continued during the past year, and interest on these deposits has amounted to \$1,732.50. The income during the year for current expenses, consisting of interest on permanent investments and other miscellaneous sources, including cash balance at the beginning of the year, amounted to \$67,484.16. Revenues and principal of funds for specific purposes, except the Freer bequest, amounted to \$69,756.48. Revenues on

account of Freer bequest amounted to \$304,436.26; aggregating a total of \$441,676.90.

The disbursements, described more fully in the annual report of the executive committee, were classed as follows: General objects of the Institution, \$64,138.85; for specific purposes (except the Freer bequest), \$44,291.25; temporary advances for field expenses, etc., in excess of repayments, \$12,769.17; expenditures pertaining to the Charles L. Freer bequest, \$251,446; cash deposited on time, \$57,500; and cash balance on hand, June 30, 1923, \$11,531.63.

The following appropriations were intrusted by Congress to the care of the Smithsonian Institution for the fiscal year 1923:

International Exchanges	\$45, 000
American Ethnology.....	44, 000
International Catalogue of Scientific Literature.....	7, 500
Astrophysical Observatory	15, 500
National Museum:	
Furniture and fixtures.....	\$20, 000
Heating and lighting.....	73, 000
Preservation of collections.....	312, 620
Building repairs.....	10, 000
Books.....	2, 000
Postage	500
	418, 120
National Gallery of Art.....	15, 000
National Zoological Park.....	125, 000
Increase of compensation.....	109, 044
Printing and binding.....	77, 400
Total	856, 564

RESEARCHES AND EXPLORATIONS

In the Institution's work in the "increase and diffusion of knowledge," scientific exploration and research expeditions in the field play an important part. There has been even more than the usual activity in this phase of the work during the past year, the Institution and its branches having initiated or taken part in 22 separate expeditions in widely scattered parts of the earth, representing many branches of science. The very limited funds of the Institution available for this important work make it necessary each year to forego opportunities to send out or join forces with other scientific organizations in expeditions which would result in valuable information and material for study and exhibition to the public in the National Museum. I will mention here only a few of the expeditions in the field during the past year, in order to show the nature and scope of the work, referring to the appended reports on the National Museum, Bureau of American Ethnology, and other branches of the Institution for accounts of the explorations undertaken by them.

GEOLOGICAL EXPLORATIONS IN THE CANADIAN ROCKIES

My geological field work in the Canadian Rocky Mountains, described in previous reports, was continued during the past year, special attention being given to securing evidence bearing on the pre-Devonian formations north of the Bow Valley, Alberta, and south along the new Banff-Windermere motor road. Difficulties were encountered during the first part of the season, owing to dense forest-fire smoke and unsatisfactory trail men, but during August and September conditions were greatly improved and the work was pushed vigorously.

A fine section of pre-Devonian strata was studied and measured in the upper part of Douglas Lake Canyon Valley, and many photographs were secured. The measured geologic section was from the base of the Devonian, above Lake Gwendolyn, across the canyon to the deep cirque below Halstead Pass, where the great Lyell limestone forms the crest of the ridge. The section includes the Ozarkian Mons formation down to the Lyell formation of the upper Cambrian.

Going south from the Bow Valley, camp was next made on the Kootenay River, about 6 miles below the mouth of the Vermilion River. The Kootenay Valley is broad and deep, with the high ridges of the Mitchell Range on the east and the Brisco Range on the west. The limestones and shales of both ranges are upturned and sheared and faulted, making it very difficult to work out the structure and the complete stratigraphic succession of the various formations. The Silurian limestones, with their fossil coral beds above the white quartzite of the Richmond transgression, were found in the upper portion of Sinclair Canyon, and not far away black shales full of Silurian graptolites. Lower down the canyon thin-bedded gray limestone yielded fossils of the Mons formation.

It is evident that in the ancient and narrow Cordilleran Sea, that extended from the Arctic Ocean 2,000 miles (3,218 km.) or more south, between the coast ranges of the time and the uplands of the central portion of the North American continent, there was a similarity of Lower Paleozoic marine life along the shores and its shallow waters. Evidences of this and of strong currents and persistent wave action occur all the way from central Nevada to Mount Robson, in British Columbia. The record of the marine life and deposits of mud and sand is most complete.

PALEONTOLOGICAL FIELD WORK IN TENNESSEE

Dr. R. S. Bassler, curator, division of paleontology of the United States National Museum, spent six weeks in June and July in a continuation of stratigraphic and paleontologic studies begun a year before in the central basin of Tennessee, in collaboration with the

Tennessee State survey. In 1921 the study and mapping of the Franklin quadrangle, an area of about 250 square miles just south of Nashville, was well advanced, and this year it was brought to completion and data secured for the preparation of a geological report upon the area, to be published by the State. Stratigraphic studies were then undertaken in contiguous areas, in which Doctor Bassler was joined by Doctors Ulrich and Mesler. The classic section at Nashville, in which the proper delimitation of the formations has long been in dispute, was studied with especial care, and large collections of fossils were secured to verify the stratigraphic results.

Regarding this section, Doctor Bassler says:

The deep-sea origin of all limestones has long been taught in spite of the trend of evidence that many limestone formations were laid down in shallow seas. The shallow-water origin of limestone is well illustrated in the section of Ordovician strata exposed near the blind asylum at Nashville, which has been studied by several generations of geologists. At the base of this section is the Hermitage formation, which was evidently formed along ancient shore lines because it is composed of beach-worn fragments of shells and other fossils. Above this comes the Bigby limestone, the source of much of the Tennessee brown phosphate, and which also is made up almost entirely of the comminuted remains of fossils. Next is the Dove limestone, an almost pure, dove-colored, lithographic-like limestone which shows its shallow-water origin in the worm tubes penetrating it and its sun-cracked upper surface. A slab of this limestone a foot thick, now on exhibition in the National Museum, well illustrates the polygonal upper surface and the penetrating worm tubes, both features indicative of the origin of the rock on old mud flats which were periodically above water and thus became sun cracked. The succeeding Ward limestone is of the more typical blue variety, but here the rock is filled with millions of fossil shells which, under the influence of weathering, are changed to silica and are left free in great numbers in the soil. This section is only a portion of the entire geological sequence at Nashville, but it well illustrates the various types of limestone outcropping throughout the central basin.

EXPEDITION TO EXAMINE THE NORTH PACIFIC FUR SEAL ISLANDS

Dr. Leonhard Stejneger, head curator of biology in the United States National Museum, was detailed at the request of the Department of Commerce, to accompany an expedition to Alaska and adjacent regions during the summer of 1922 to ascertain the status of the fur seal herds in the North Pacific Ocean since their protection through the treaty of 1911 between the United States, Russia, Japan, and Great Britain. The first seal rookeries visited were those of the Pribilofs, where the increase in number of seals on the beaches is very remarkable, and Doctor Stejneger predicts a complete restitution of the fur seal herd to its former maximum for the not distant future. A new method of stripping the skin from the dead seal and subsequent cleaning of the skin was being adopted on an extensive scale and was found to be a great improvement over the old method.

On Bering Island of the Commander Islands, the next stop of the expedition, conditions were quite the reverse of those on the Pribilofs. The south rookery had long since ceased to exist and the great north rookery had been greatly reduced. On his last visit to this rookery in 1879, Stejneger had estimated the number of breeding seals there at 30,000. At the time of the present visit, there were scarcely 2,000 left.

The expedition next visited the Japanese fur seal island usually known as Robben Island in the Okhotsk Sea. Here the number of fur seals has gradually increased until now they occupy not only the entire eastern beach but are extending the rookery at both ends on to the west side of the island. The Japanese have followed closely the methods employed in managing the American seal herd on the Pribilofs, and the result is most instructive in showing conclusively that "protection does protect." Important information regarding the Russian fur seal islands was obtained from Mr. Koltanovski and Colonel Sokolnikof, and from Yokohama Doctor Stejneger took passage back to the United States, having completed the inspection of the fur seal rookeries.

BOTANICAL EXPLORATION IN COLOMBIA

From April to October, 1922, Dr. Francis W. Pennell, of the Philadelphia Academy of Natural Sciences, and Mr. Ellsworth P. Killip, of the National Museum, carried on botanical exploration in the Republic of Colombia. The expedition was organized by several institutions as part of a general plan for the botanical study of northern South America. Financial assistance was also given by Mr. Oakes Ames, who was especially interested in the orchids of the region.

Entering the country at Buenaventura on the Pacific side, the expedition established headquarters at La Cumbre in the Western Cordillera, for the purpose of studying the vegetation of the central part of this range. Descending to the city of Cali, the party proceeded up the Cauca Valley to Popayán, and from this point explored the southern portions of both the central and western Cordilleras. Later the expedition visited Salento, in the northern part of the Central Range, and Ibagué and Bogotá, collecting material at historic localities along the Quindiu Trail. Approximately 7,200 members were collected, sufficient material being secured to make up equal sets for each of the institutions represented in the expedition.

In his report on the work, Mr. Killip says:

As might be expected from its physiography, the vegetation of Colombia is extremely diverse. Within a few miles may occur a luxuriant tropical flora, the more open woods of the temperate zone, and the low alpine growth familiar on our American mountain tops. Again, as in the Dagua Valley, one may ride through a dense rain forest, filled with ferns, mosses, and aroids, to emerge

suddenly in an arid desert-like region, where cacti and acacias are the conspicuous plants.

So inadequately known is the flora of Colombia that even along the regular routes of travel many species are found that are either new, unrepresented in American herbaria, or known only from specimens preserved in European collections.

The botanical collection resulting from this expedition is one of the largest and most important ever obtained in Colombia.

EXPLORATION OF THE PALEOLITHIC REGIONS OF FRANCE AND SPAIN

During September, 1922, Mr. M. W. Stirling, of the National Museum, explored the paleolithic regions of southern France and northern Spain. Besides visiting all of the important sites where remains of ancient man have been discovered, the expedition entered a great many caves previously unknown to science. Regarding the great promise of the region for archeological work, Mr. Stirling reports as follows:

The idea has become prevalent in America that this region has been practically exhausted archeologically. Although the previous existence of paleolithic man in this locality has been known for half a century, it may be truly said that the work of exploration has hardly begun.

The habitations of the Stone Age are closely linked with the limestone formation which overlies large areas in this part of Europe. These may be said to fall into two classes, i. e., rock shelters and caverns. The former are undercuts in the limestone made by the rivers in the early Pleistocene or late Pliocene. A general elevation of the land has caused the streams to deepen their channels, thus leaving the undercuts well above the surface of the water. These were utilized as dwelling places by paleolithic man and in many instances were artificially modified. There are literally miles of relic-bearing deposits of this class that have not yet been touched. The possibilities in this field are very great.

The caverns of the Dordogne region are for the most part comparatively small, while those in the department of Arriege are immense caves of a most spectacular nature. Of the former class are the grottoes of Font du Gaume, Combarelles, La Mouthe, Marsoulas, Montesquieu, and others. Of the latter class are the immense caves in the neighborhood of Foix, as for example, Salignac, Ussat, and Niaux. The tunnel of Mas d'Azil is the remnant of such a cave.

Many of these caverns have become blocked with sediment owing to the fact that they frequently slope downward from the entrance. Messrs. Stirling and Patton entered at least a dozen such caves which had become sealed at varying distances from their mouths. The opening of such caves has heretofore been left entirely to chance. Scientific endeavor at this work should produce most fruitful results. The sealing of these caves has been a fortunate accident of nature, since the contents are by this means preserved intact.

Of the regions visited, that in the neighborhood of Altamira, in Spain, and Ussat, in France, give most promise of rich returns to the archeologist.

CENTENARY OF THE BIRTH OF SPENCER FULLERTON BAIRD

A meeting was held in the auditorium of the National Museum on the evening of February 3, 1923, to celebrate the centenary of the

birth of Spencer Fullerton Baird, second secretary of the Smithsonian Institution, the virtual founder of the United States National Museum, the creator and head of the United States Fish Commission, and a prime mover in the establishment of the United States Geological Survey and the Bureau of American Ethnology. The meeting was presided over by Representative Frank L. Greene, a member of the Board of Regents of the Institution, and the following addresses were delivered: "Baird, the man," by Dr. William Healey Dall; "Baird and the Smithsonian Institution and its branches," by Dr. Charles G. Abbot; "Baird at Woods Hole," by Prof. Edwin Linton; "Baird and the Fisheries," by Prof. David Starr Jordan; and "Baird, the Naturalist," by Dr. C. Hart Merriam.

In the afternoon, preceding the formal celebration, the National Baird Memorial Committee met in the National Museum to decide upon the form of the memorial or memorials to Baird. The committee was composed of delegates appointed by 54 scientific societies and institutions from various parts of the country, with the following officers:

Honorary president, Dr. William H. Dall; president, Dr. Charles D. Walcott; vice presidents, Mr. George R. Agassiz, Dr. Alexander Graham Bell (deceased), Prof. Frank W. Clarke, Prof. Stephen A. Forbes; Prof. David Starr Jordan, Prof. Edwin Linton, Prof. Edward S. Morse, Prof. Henry Fairfield Osborn, Prof. Addison E. Verrill, and Dr. Robert S. Woodward; secretary, Dr. Paul Bartsch. At this afternoon meeting it was announced that appropriate exercises were held during the morning, when wreaths were placed on the grave of Baird in Oak Hill Cemetery, the bust of Baird in the American Museum of Natural History, the Baird memorial boulder of the American Fisheries Society at Woods Hole, and the Baird memorial tablet at the Bureau of Fisheries Building in Washington, and that the mayor of Reading, Pa., had been requested to decorate the house in which Baird was born.

The report of the national committee, announced at the evening meeting, is as follows:

1. That Congress be memorialized to establish in the city of Washington a museum of fisheries and oceanography, with laboratories and a public aquarium, as a memorial to Spencer Fullerton Baird.

2. That there be established a fund for the encouragement of research and exploration in the directions in which Spencer Fullerton Baird was a leader.

3. It was the sense of the meeting that the name of Baird be given to the laboratory of the Bureau of Fisheries at Woods Hole, Mass.

PRESENTATION OF BUST OF JEANNE D'ARC

On February 23, 1923, there was presented to the Smithsonian Institution for the American people a bronze bust of Jeanne d'Arc by Madame Berthe Girardet, of Neuilly, France. This bust, accepted by your secretary on behalf of the Board of Regents of the Institution, is a gift from the sculptress through Mrs. Grace Whitney Hoff, "in memory of what the American soldiers did in France at a crucial time of need—in gratitude to the mothers, to the wives, to the sisters and sweethearts, and to all those who gave their dear ones whose blood has mingled with the soil of France." The bust is installed in the National Gallery of Art.

HAMILTON FUND LECTURE

The Rev. James Hamilton, in 1875, placed under the administration of the Smithsonian Institution a sum of money, designated as the Hamilton fund, the interest from which is to be used for "lectures on scientific or useful subjects." Under the auspices of this fund there was delivered on April 18, 1923, an interesting lecture by Dr. Sven Hedin, the noted Swedish explorer, on his discoveries of ancient cities and manuscripts in eastern Turkestan and his latest explorations in southern Tibet. The lecture was profusely illustrated with lantern slides, and Doctor Hedin described graphically the dangers and hardships incident to a journey through the great desert regions in which he worked. The lecture, to which the Washington public was invited, had a large attendance.

DISTRICT OF COLUMBIA NATURE STUDY EXHIBIT

Four of the foyer rooms in the New National Museum have been set aside for a local exhibit, which, it is hoped, will meet a long-felt want of teachers and students and people generally interested in the fauna and flora of the District of Columbia and its immediate vicinity.

Two of the rooms are devoted to the birds and it is intended to install a complete representation of all species reported for the District. A third room is devoted to the mammals, reptiles, batrachians, and fish of the District, while the fourth room has the commoner insects—butterflies, dragonflies, beetles, etc.—and swinging frames containing beautifully pressed specimens of local plants. It is intended to change the contents of these frames as the season advances, so that anyone wishing to know what is in flower at the particular time in question will find the specimen represented in the frame in its regular systematic position, as well as a photograph of the habitat and some detail pictures. Here, too, is installed a stereomotorgraph

which alternately shows series of pictures of plants and birds, the plants as they come into flower and the birds about their nest, feeding stations, or bird baths.

Judging from the attendance which these exhibits have already called forth and the numbers of inquiries which have been made by teachers and persons interested, there is no question about the advisability of having furnished the school system and nature lovers of Washington these aids to visual education.

TWENTIETH INTERNATIONAL CONGRESS OF AMERICANISTS

The twentieth meeting of the International Congress of Americanists, held at Rio de Janeiro, Brazil, in August, 1922, was attended by Dr. Walter Hough and Dr. Aleš Hrdlička, of the National Museum, who represented the Smithsonian Institution and were also designated by the State Department to represent the United States. Means were provided to repay the expenses of the delegates by the Carnegie Endowment for International Peace. A great many papers of scientific value were presented in several languages at the Congress, and the delegates feel that a great stimulus was given to the promotion of anthropological science, especially in Brazil.

PUBLICATIONS

The Institution and its branches issued during the year a total of 100 volumes and pamphlets, of which there were distributed 139,666 copies, including 130 volumes and separates of the Smithsonian Contributions to Knowledge, 18,801 volumes and separates of the Smithsonian Miscellaneous Collections, 25,229 volumes and separates of the Smithsonian Annual Reports, 3,016 Smithsonian special publications, 72,529 volumes and separates of the publications of the National Museum, 17,694 publications of the Bureau of American Ethnology, 816 publications of the National Gallery of Art, 1,309 volumes of the Annals of the Astrophysical Observatory, 31 reports on the Harriman Alaska Expedition, and 74 reports of the American Historical Association.

Through its publications the Institution carries out one of its primary functions, the "diffusion of knowledge among men." Many of its publications are the results of scientific researches conducted by members of the staff, others are prepared by outside scientists who have carried on special investigations on the collections of the National Museum and still others are intended for the general reader who takes an interest in the progress of science but is not benefited by the more technical papers mentioned above. In this last class comes the General Appendix to the Smithsonian Annual Report, which consists of a series of articles by authorities in the matters treated, outlining the more noteworthy and interesting advances in

many lines of scientific work, including physics, chemistry, astrophysics, geology, biology, and anthropology. These are written in a style to attract the average intelligent reader, and there is a very general demand for the reports. A cataloguer in the office of the Superintendent of Documents, where all public documents are distributed, has placed the Smithsonian report first in point of number of requests from libraries to receive this publication.

The publications of the National Museum and of the Bureau of American Ethnology are mentioned in detail in the report on publications, appended hereto.

Nine papers were issued during the year in the series of Smithsonian Miscellaneous Collections, among which may be mentioned one by your secretary resulting from his geological field work in the Canadian Rocky Mountains; a timely paper by Mr. Mitman, of the Museum staff, on "Some Practical Aspects of Fuel Economy"; and a contribution from Dr. J. Walter Fewkes, chief of the Bureau of American Ethnology, on the "Designs on Prehistoric Pottery from the Mimbres Valley, New Mexico," which was fully illustrated with striking Indian designs.

Allotments for printing.—The congressional allotments for the printing of the Smithsonian reports and the various publications of the branches of the institution were practically used up at the close of the year. The appropriation for the coming year ending June 30, 1924, totals \$77,400, allotted as follows:

For printing and binding the Annual Reports of the Board of Regents, with general appendixes, the editions of which shall not exceed 10,000 copies.....	\$10,000
Under the Smithsonian Institution: For the annual reports of the National Museum, with general appendixes, and for printing labels and blanks, and for the bulletins and proceedings of the National Museum, the editions of which shall not exceed 4,000 copies, and binding, in half morocco or material not more expensive, scientific books and pamphlets presented to or acquired by the National Museum Library.....	37,500
For the annual reports and bulletins of the Bureau of American Ethnology, and for miscellaneous printing and binding for the bureau.....	21,000
For the annual report of the National Gallery of Art and for printing catalogues, labels, and blanks.....	1,000
For miscellaneous printing and binding:	
The International Exchanges.....	200
The International Catalogue of Scientific Literature.....	100
The National Zoological Park.....	300
The Astrophysical Observatory.....	300
For the annual report of the American Historical Association.....	7,000
	<hr/>
	77,400

Provided, That the expenditure of this sum shall not be restricted to a pro rata amount in any period of the fiscal year.

Committee on printing and publication.—The function of the Smithsonian advisory committee on printing and publication is to make recommendations to the secretary regarding the technical merit and suitability of all manuscripts submitted for publication by the Smithsonian Institution or its branches, and also to consider all other matters relating to printing and binding under the institution. During the past year seven meetings were held and 104 manuscripts acted upon. The membership of the committee is as follows: Dr. Leonhard Stejneger, head curator of biology, National Museum, chairman; Dr. George P. Merrill, head curator of geology, National Museum; Dr. J. Walter Fewkes, chief, Bureau of American Ethnology; Mr. N. Hollister, superintendent, National Zoological Park; and Mr. W. P. True, editor of the Smithsonian Institution, secretary.

LIBRARY

Much has been accomplished during the year toward better library service. The number of publications loaned during the year reached a total of 12,076, and fully as many were consulted without being taken out. A list has been prepared each day of the principal contents of scientific and technical periodicals received for the Smithsonian Deposit at the Library of Congress, and copies are circulated among the heads of scientific bureaus under the Smithsonian Institution. The subject catalogue of the Museum library has been increased by 4,400 cards, and progress has been made in the arrangement of cards of the Concilium Bibliographicum, received since the close of the war.

The third volume of the "Bibliography of Aeronautics," covering the years 1917 to 1919, inclusive, compiled by the assistant librarian of the Smithsonian Institution, Mr. Paul Brockett, was issued during the year by the National Advisory Committee for Aeronautics.

Of the 10,938 volumes and other publications added to the library, 5,719 were for the Smithsonian Deposit at the Library of Congress, 4,285 for the National Museum, and the others for the remaining libraries administered under the Smithsonian Institution.

NATIONAL MUSEUM

While without increased financial resources it has been impossible for the Museum during the year to increase the scope of its exhibits and of their usefulness to the public, nevertheless much has been accomplished along the lines of filling in gaps in existing collections and of increasing their value through classification and arrangement. The Museum has been fortunate in being able to keep together most of its scientific staff. In many cases this has been possible only because of the devotion of the persons and their willingness to accept

employment in what should be their leisure hours in order to meet living expenses. Better conditions are expected to result, however, from the passage by Congress of the reclassification act of 1923, which becomes effective July 1, 1924.

The Museum acquired during the year a total of 217,611 specimens. While numerically this is only 60 per cent as many as received during the previous year, many of the accessions are of exceptional value, either intrinsically or from a scientific point of view. The distribution of duplicate specimens, mainly to educational institutions, totaled 9,131 specimens, classified and labeled. About one-half of these were in regular sets already prepared for shipment, and the other half were specially selected to meet particular needs. Nearly 35,000 duplicates, chiefly relating to botany and geology, were sent out in exchange, resulting in the acquisition of much desirable material. Over 12,000 specimens were lent to specialists for study purposes. The material received by the Museum during the year is described somewhat fully in the report of the administrative assistant in charge, appended to this report, but it may be well to here mention briefly some of the outstanding accessions. Among much material in anthropology, there may be mentioned an expressive carved stone figure from the Makah Indians; casts of the famous La Quina and Obercassel skulls and skeleton; a series of archeological specimens from Haiti; an ethnological collection from Formosa; and casts of the busts of the heretic Pharaoh, Amenophis IV, and his queen.

The biological specimens received during the year, while fewer in number, compare favorably in scientific value with those of previous years and probably are above the average. Perhaps the outstanding accession in biology was the Evezard collection of recent mollusks presented by the late John B. Henderson, while another of great scientific interest is the series of Opalinid ciliate infusorians prepared by Prof. Maynard M. Metcalf. A significant feature of the year's accessions is the fact that some of the most important are from China as a result of a deliberate effort to improve systematically the study material from the Palearctic region which is of fundamental importance for a full understanding of our North American fauna. Several expeditions from which biological material may be expected to come to the Museum are now in the field in China. A number of other expeditions to South America and elsewhere during the year have resulted in much valuable material, the National Herbarium especially being enriched. Striking new exhibits in the department of biology include several species of Australian mammals, a Malay tapir, and a gorilla collected in French Congo by Mr. Aschemeier, of the Museum staff. The scientific staff has continued to carry on research work on the study collections, resulting in the publication

of many papers in the various Museum series. The total number of specimens of animals and plants now in the Museum collections is estimated to exceed 7,000,000.

Among the important accessions in the department of geology may be mentioned the valuable paleontological collection of the late Orestes St. John, consisting principally of fossil fishes, donated by Dr. Frank Springer, and a collection of not less than 10,000 specimens, mainly fossil plants, presented by the heirs of the late R. D. Lacoe, of Pittston, Pa. The residuary portion of the meteorite collection of the late Prof. H. A. Ward was presented by Mrs. Coonley Ward, and 13 additional accessions of meteorites were received. A number of important mineralogical specimens were acquired, largely through exchanges, including a portion of a large boulder of jade received from Col. W. B. Thompson and a fine specimen of crystallized descloizite from southwest Africa. Several unusual cut gems were purchased through the Chamberlain endowment fund. An important phase of the work of the department of geology consists in furnishing assistance to schools and students, chiefly through the distribution of materials needed in their studies. Eighty-one educational institutions were thus aided during the year.

The collections of textiles, wood technology, organic chemistry, foods, and medicine, all under the supervision of the curator of textiles, received many valuable specimens, numbering over 2,000. Among the most important of these are a large series of specimens of pyralin, bakelite, condensite, and cellulose acetate, all substitutes for natural raw materials, such as ivory, bone, horn, tortoise shell, amber, etc., the supplies of which are growing scarcer every year; beautiful specimens of silks, woolen fabrics, and mohair upholstery textiles; an exhibit showing the process of manufacture of double-tipped matches; and specimens showing the use of chaulmoogra oil derivatives in the treatment of leprosy in Hawaii.

In the divisions of mineral and mechanical technology, graphic arts, and history, an unusually large and valuable series of objects has been accessioned during the year. The divisions of mineral and mechanical technology, in their conservation program, cooperated with Mr. S. S. Wyer in preparing a work under the title "The Smithsonian Institution's Study of Natural Resources Applied to Pennsylvania's Resources," which was distributed free to school teachers throughout Pennsylvania and used in certain courses in the grade schools. Seven loan exhibits shown in the division of graphic arts brought the division prominently before the local public, and two traveling exhibits prepared in the division were shown in various cities. The division of history received, besides several other important accessions of military, naval and antiquarian material, the

entire collection of numismatic material formerly exhibited in the United States mint in Philadelphia, transferred to the Museum owing to the closing of the mint to the public.

A number of field expeditions in which the Museum was interested resulted in greatly enriching the collections in all departments, though mainly in biology and geology. These expeditions are described in the report on the Museum appended hereto. The usual large number of meetings, congresses, and receptions were held in the auditorium and rooms of the Natural History Building. Visitors to the Natural History Building totaled 508,518, to the Arts and Industries Building, 259,542, to the Smithsonian Building, 95,168, and to the Aircraft Building, 42,904. The Museum published during the year 10 volumes and 42 separate papers, of which there were distributed a total of 72,529 copies.

NATIONAL GALLERY OF ART

In the National Gallery, the year has seen substantial advance in a number of directions, although additions to the art collections have not been so numerous as in several previous years. The time of the staff has been devoted largely to the receipt, installation, and care of the collections; to completing the records and labeling; and to the preparation of matter for publication for the purpose of arousing interest in the National Gallery, especially in its vital need of a gallery building. A recent act of Congress authorizes the raising of funds for a National Gallery Building and provides a site in the Smithsonian Park for its erection, and the gallery has made every effort during the year to bring forcibly to the attention of the public the urgency of providing a suitable building to take care of the growing national art collection and to offer better inducements to prospective donors to the Nation of valued art material. Furthermore, there must be in America a National Gallery of Art Building if we are to take a respectable place among the civilized nations of the world in the field of art, and the director of the gallery has endeavored in several published articles to make known this national shortcoming and to stir the pride of a people not accustomed to take a second or third place in any field worthy of their ambition.

The National Gallery Commission held its second annual meeting on December 12, and numerous important problems connected with the work of the gallery and with its future were considered. Following the reports of committees, a new committee was appointed to look after the gallery's interests in the final disposition of purchases made from the Ranger bequest fund.

The 21 portraits of distinguished leaders of America and other allied nations in the war with Germany, painted by a number of

leading American painters under the auspices of the National Art Committee, have now returned to the National Gallery and will remain on permanent exhibition, after having been displayed in 25 of the larger cities through the offices of the American Federation of Arts.

The gallery received by gift during the year a number of paintings and other art works, and several interesting collections were loaned, among them the famous McFadden Collection of 43 portraits and landscapes of the British School, which is deposited in the gallery pending its permanent housing by the city of Philadelphia. Several special exhibitions were held in the gallery, including an exhibition of American Handicrafts assembled and circulated by the American Federation of Arts, and a collection of antique Etruscan, Greco-Roman, and Byzantine jewelry, ancient glassware, and pottery exhibited under the auspices of the Archæological Society of Washington.

The first catalogue of collections to be issued since the establishment of the gallery as a separate unit appeared during the year. The catalogue contains an account of the development of the art interests of the Smithsonian Institution and an outline of the organization of the gallery, followed by a list of the art works with brief biographies of the artists, and is illustrated with 25 plates of certain of the most noteworthy paintings and sculptures in the gallery.

FREER GALLERY OF ART

The examination, classification, and preliminary cataloguing of Chinese and Japanese stone sculptures and jades, begun in 1922, was completed during the year. New work begun includes the preliminary cataloguing and final storage of Chinese and Japanese bronzes, lacquers, and wood sculptures, Near Eastern and Egyptian pottery, and miscellaneous objects of bone, ivory, metal, glass, etc. The autumn, winter, and early spring were largely devoted to the installation of exhibits and preparations for the formal opening of the gallery to the public on May 2, 1923.

For the opening week, there were issued 3,300 invitations, and the gallery was then opened to the public. From May 9 until the end of the period covered by the report of the gallery, June 30, the total attendance was 32,648. Beginning June 11, the building was closed on Mondays, making the exhibitions available on Sundays to many people who are unable to come on week days.

The field work of the gallery included a trip to Europe by Miss Guest to attend as a delegate from the gallery the meetings of the Société Asiatique de Paris, held in Paris from July 10 to 13, follow-

ing which she devoted two months to a study of various collections of Oriental art in France, England, and Germany. On February 12, Mr. Bishop, of the gallery staff, left for China, in charge of an archeological expedition sent out under the joint auspices of the Freer Gallery of Art and the Museum of Fine Arts, Boston. Up to the close of the year, Mr. Bishop's chief concern was with matters of organization, which he has now settled very successfully. He also visited several sites of great archeological interest and made observations of importance to the future work of the expedition.

BUREAU OF AMERICAN ETHNOLOGY

The chief has endeavored to expend in the most economical manner the funds appropriated by Congress for "continuing ethnological researches among the American Indians and the natives of Hawaii, etc.," although considerable difficulty has been encountered owing to the greatly increased cost of field work and maintenance. There has been a great awakening of interest in matters concerning the aboriginal inhabitants of America, and never before has there been such a general demand for the published works of the bureau. The great archeological discoveries in Egypt have created a new popular interest in the Science of Man, and the chief is endeavoring to meet this situation by increasing the output of the bureau in the form of popular publications in addition to the usual technical works. The past year's work includes archeological and historical study of the Indians as well as work on documentary history. Somewhat detailed accounts of the various researches carried on during the year are contained in the report of the chief of the bureau, Appendix 4 of this report, so that it will here be necessary only to indicate the character and scope of the work.

From July to September, 1922, the chief completed the excavation and repair of Pipe Shrine House on the Mesa Verde National Park, Colorado, begun the previous year. This exceptional ruin is now open for the inspection of visitors to the park. He also excavated and repaired Far View Tower, an instructive circular ruin with three subterranean kivas, probably an outlook for observation of the sun and ceremonies connected with the sky god. In June, 1923, the chief visited various localities in the neighborhood of Deming, southern New Mexico, for the purpose of examining and obtaining specimens of a beautiful form of prehistoric Indian pottery which had been discovered in that region. The remarkable pictures on this pottery throw considerable light on the ethnology of an ancient people of whom we would otherwise have practically no knowledge.

Dr. John R. Swanton completed three manuscripts for publication during the year, besides carrying on important linguistic and

ethnological researches in the office. Dr. Truman Michelson began the year conducting ethnological researches among the Fox Indians of Iowa, where he collected sufficient material for a manuscript on the origin of one of the Fox societies. Tribal dissensions cut short Doctor Michelson's stay among the Fox and he undertook a reconnaissance among the Potawatomi of Wisconsin, the Chippewa at Reserve in the same State, the Ottawa of Michigan, the Delaware-Munsee of Lower Canada, and the Montagnais of Lake St. John. In May, 1923, he left for the field to make a reconnaissance of the Algonquian tribes of eastern United States and Canada, including the Labrador peninsula.

Mr. John P. Harrington prepared several manuscripts for publication during the year, and carried out linguistic researches with Mr. Cipriano Alvarado, a Quiché Indian of Guatemala. In May, 1923, Mr. Harrington went to Santa Barbara, Calif., for the purpose of continuing his researches on the Indians of that State. He secured a large quantity of manuscript material bearing on myths, place names, historical notes, early life and customs, genealogies, and Indian songs. He also participated in the excavation of the famous Burton Mound on the beach at Santa Barbara, which resulted in the discovery of a great mass of Indian skeletons, trinkets, and utensils. Mr. J. N. B. Hewitt completed two manuscripts for publication, and in May, 1923, left for ethnological field work among the Six Nations of Iroquois near Brantford, Ontario, Canada, where he elaborated and revised texts recorded there previously and also recorded much valuable information relating to the institutions of the league. Later he visited the Onondaga Reservation near Syracuse, N. Y. Mr. Francis La Flesche was engaged during most of the year in assembling his notes for the third volume of his work on the Osage Tribe.

The report on the bureau then discusses, under special researches, the work of Miss Frances Densmore on the Indian music of the Yuma, Mohave, and Papago Tribes; the archeological investigations by Mr. W. E. Myer of ancient Indian mounds in central Tennessee; archeological work on the Stratman cave in Maries County, Mo., by Mr. Gerard Fowke; and field studies by Mr. John L. Baer on the banner stones and pictographs in the Susquehanna River region, Pennsylvania.

The bureau published during the year two annual reports with lengthy accompanying papers and two bulletins. Several other publications were in press at the close of the year. Of the bureau series, there were distributed during the year a total of 17,694 copies.

INTERNATIONAL EXCHANGES

The total number of packages of scientific and governmental publications sent abroad and received from foreign agencies for distribution in this country during the year was 377,826, weighing 492,816 pounds. This is a decrease in number of packages and in weight from the previous year, owing partly to the smaller size of the publications handled this year. These publications were forwarded in 2,223 boxes, in addition to which 40,000 packages were sent direct to their destinations by mail whenever a sufficient quantity for box shipments had not accumulated when the regular monthly consignments were forwarded.

Exchange relations were resumed with Roumania during the year, the Institutul Meteorologic Central at Bucharest acting as the official Roumanian exchange bureau. Conditions in Russia and Turkey had not sufficiently improved at the close of the year to warrant the establishment of official exchange bureaus in those countries, but the Institution has arranged with the American Friends Service Committee to forward to Russia the large accumulation of exchange material for correspondents in that country. Seventy boxes were thus forwarded to Russia during the year. The State Library (Riigiraamatukogu), Reval, was designated as the exchange agency for Esthonia.

There were sent to depositories abroad during the year 57 full sets of United States official documents and 38 partial sets, and the Congressional Record was exchanged with 44 establishments abroad.

NATIONAL ZOOLOGICAL PARK

The actual number of animals on exhibition at the close of the year was greater than in any previous year, and the scientific value of the collection is greater than ever before. For the fourth successive year the number of visitors to the park has exceeded 2,000,000, and its value in natural history instruction is again shown by the fact that 171 schools, classes, and other organizations visited the park during the year, with a total of 14,185 individuals. Friends of the park have been even more than usually generous in presenting animals, 266 specimens having been thus added during the year. Of special interest among these may be mentioned a number of desirable animals presented by Mr. Victor J. Evans, including specimens of the frog-mouth and New Guinea fruit pigeon; valuable collections of South American animals contributed by Hon. Henry D. Baker and Mr. William J. LaVarre; a collection of animals presented by Mr. Gordon MacCreagh, including the rare red ouakari monkey and the matamata turtle; and a number of interesting animals from southern Mexico collected by Dr. William M. Mann.

At the close of the year there were in the collections a total of 1,768 animals, an increase of 87 over the previous year*. This total represents 498 different species, including 184 species of mammals, 271 of birds, and 43 of reptiles. There were born or hatched in the park during the year 80 mammals and birds, while the death rate has again been kept at a very low mark. Sixty-six surplus mammals and birds were sent away in exchange to other zoological gardens, which resulted in securing some very desirable specimens for the park.

Among the improvements undertaken during the year the superintendent's report mentions the complete reconstruction of the wolf and fox dens below the sea-lion pool, making the quarters for these animals much more comfortable and sanitary and greatly improved in appearance. The principal construction during the year was the continuation of the grading of the area left vacant through the changing of the main automobile road through the park. Here will soon be available a large area of flat ground, on which paddocks are being completed for Rocky Mountain goats, red deer, barasingha deer, and Japanese deer, Indian buffaloes, tahr goats, aoudads, axis deer, and similar species. The outdoor cages for rhesus and other monkeys were all repaired, repairs to the ostrich inclosure were made, and safety guards placed along the fence in front of the main bear dens. The principal needs of the park, as enumerated by the superintendent, are a suitable restaurant building, which has been urged for many years, a new bird house to replace the old temporary one, which is far too small and in very bad condition, and the establishment of a reasonable fund to enable the park to grasp the occasional opportunities offered to secure rare and desirable animals which otherwise it is impossible to obtain.

ASTROPHYSICAL OBSERVATORY

The observatory now occupies a number of frame structures south of the Smithsonian Building, at Washington; a cement observing station and frame cottage for observers on Mount Wilson, Calif.; an observing station at Montezuma, Chile; and a new observing station on Mount Harqua Hala, Ariz.; the last erected from funds donated for the purpose by Mr. John A. Roebling, of New Jersey. At Washington no observations were attempted, but as much time as possible was devoted to computations necessary to the following:

- (1) The search for systematic errors in the work of Mount Harqua Hala, Ariz., and the application of carefully determined corrections thereto.
- (2) The publication of a comparison of two years of observations at Mount Harqua Hala, Ariz., and Mount Montezuma, Chile.
- (3) The preparation of a new set of curves for use from January 1, 1923, in the short method of solar constant determination at Montezuma, Chile.

(4) The search for systematic errors and the application of carefully determined corrections to Montezuma results on the new basis.

(5) The reductions of observations made at Mount Wilson in 1922 on the form of the solar spectrum energy curve and on the spectrum energy curves of 10 of the brighter stars.

This large computing program has resulted in putting the two stations on an equal footing in every possible way.

At Mount Wilson the director and Mr. Aldrich redetermined the form of the solar spectrum energy curve, varying the procedure as far as possible so as to get several independent checks on the results. They also accomplished the difficult task of the observation of the prismatic energy spectrum of 10 of the brighter stars in the focus of the 100-inch reflector on Mount Wilson. The results of both of these researches were published in the Smithsonian Miscellaneous Collections, volume 74, No. 7, 1923.

The two observing stations at Mount Harqua Hala, Ariz., and Mount Montezuma, Chile, have continued in operation throughout the year, and the results have been very numerous. They had not been critically compared at the close of the year.

The work on solar radiation, begun in 1903, has been steadily improved, until with the continuous year-round occupation for two years of two first-rate observing stations the decisive test has been made, proving the substantial character of solar variation. In short, the director believes that there is no longer a reasonable doubt that the sun varies or that the observations can reveal these variations satisfactorily. It is now a question for meteorologists whether these variations are of importance in weather forecasting.

Just after the close of the fiscal year some preliminary observations were made on changes in the appearance of the sun accompanying changes in the output of radiation. Two years of record prints from direct photographs and spectroheliograms of the sun made at the Mount Wilson Solar Observatory were compared with the corresponding two-year records of solar radiation, and there were established four general rules or principles connecting the solar radiation with the sun's visible appearance.

INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE

In the report of the Regional Bureau of the International Catalogue of Scientific Literature for 1922 attention was called to an international convention to be held at Brussels during July, 1922, to consider the affairs of the catalogue and to the proposals to be submitted by the Smithsonian Institution. It is satisfactory to be able to report that at this convention these proposals formed the basis of the resolution whereby all the countries represented agreed

to keep alive the various regional bureaus until international affairs would allow reorganization and resumption of publication. There appears to be no question of the need of an international bibliography of science and of international cooperation in its production; therefore as the International Catalogue of Scientific Literature is the only such organization in existence it is the logical foundation on which to base future operations, whether these operations are to be aided through private endowments or official guarantees.

NECROLOGY

ALEXANDER GRAHAM BELL

Alexander Graham Bell, a regent of the Smithsonian Institution from 1898 to 1922, died at his summer home in Nova Scotia on August 2, 1922. Doctor Bell, best known for his invention of the telephone, was born in Edinburgh, Scotland, in 1847, and was educated at Edinburgh and London universities. He later received many honorary degrees from universities in this country and abroad. A patent was granted on March 17, 1876, for his invention of the telephone, and in 1883, with C. A. Bell and Sumner Taintor, he invented the graphophone. His many other notable inventions for the benefit of mankind include the photophone, induction balance, and telephone probe for painless detection of bullets in the human body.

He was deeply interested in the subject of deafness and its correction, and founded and endowed in 1887 the Volta Bureau for the increase of knowledge relating to the deaf. He was the author of many scientific and educational monographs.

Doctor Bell occupied a prominent place in the affairs of the Smithsonian Institution during the 24 years of his membership on the board of regents, serving continuously from the time of his appointment to the board as a member of its executive committee.

The loss of his active interest and sound advice will be deeply felt by the institution.

JOHN BROOKS HENDERSON

John Brooks Henderson, regent of the Smithsonian Institution since 1911, died January 4, 1923, at the age of 53. Mr. Henderson was early attracted to scientific work and shortly after his graduation from Harvard undertook his first expedition to the West Indies in quest of land mollusks. These, together with marine mollusks, he made his special study, and in the course of his work he made many collecting trips to the Greater and Lesser Antilles. His first paper on mollusks was published in 1894, and in the succeeding years his con-

tributions on this subject appeared in various journals and in the publications of the United States National Museum. As a result of his expeditions many thousands of valuable specimens have been added to the museum collections.

As a regent of the institution, Mr. Henderson took a keen and active interest in all its affairs. During the year preceding his death he served on the executive committee of the board of regents.

HENRY N. SPOTTSWOOD

Henry N. Spottswood, employed by the institution in various capacities since 1889, died on December 1, 1922. Coming to the institution as copyist in the National Museum and promoted through various grades to clerk in the international exchange service, Mr. Spottswood served the institution efficiently for over 33 years.

Respectfully submitted.

CHARLES D. WALCOTT, *Secretary*.

APPENDIX I

REPORT ON THE UNITED STATES NATIONAL MUSEUM

SIR: I have the honor to submit the following report on the operations of the United States National Museum for the fiscal year ending June 30, 1923.

Much has been accomplished this year along long-established lines of endeavor. Without increased financial resources to grasp the many opportunities for widening the scope of the exhibits and of their usefulness to the public, efforts were mainly concentrated on filling gaps in existing collections and on increasing their value and usefulness through classification and arrangement, the two primary objects of the Museum as given in the fundamental act. The Museum has continued, as in the past, to be greatly aided in this work by workers in other governmental departments. For instance, the Museum pays for the services of but three persons in connection with the vast insect collection. However, this collection has had during the year most of the time of 15 entomologists and a fluctuating number of preparators—usually about 25 persons in all. With so many workers great progress has been made in studying and arranging the collection. Here, as elsewhere in the Museum, progress was retarded to a certain extent by lack of supplies, which the Museum is unable to furnish with its very limited maintenance fund.

The organization of the Museum has been but slightly changed. In August, 1922, the old collections of animal and vegetable products were combined in a new section of organic chemistry in the department of arts and industries, and an aid for that section was added to the scientific staff.

An exchange of collections was made between two divisions of the Museum on July 1, 1922, by which the division of history took over the custody of the small arms collection in the northwest court of the Arts and Industries Building, which has been built up by the division of mechanical technology, and the latter relieved the division of history of the aircraft collection exhibited in the Aircraft Building.

Great difficulty has been experienced in maintaining the quota of watchmen necessary for guarding the buildings. The conditions under which the watchmen are required to work here are more onerous and exacting than in any other bureau of the Government.

With the funds at present available it has not been possible, especially since the Natural History Building has been opened on Sundays, to grant the watchmen time off in lieu of Sundays and holidays. This is done in some of the Government departments and every effort is being made to secure the additional funds needed to make the watch service in the Museum as attractive as elsewhere.

The Museum has, however, been fortunate in being able to keep together most of its trained workers on the scientific staff. In a number of instances this has been possible only because of the devotion of the persons and their willingness to accept employment in what should be their leisure hours, in order to meet their current expenses. This spirit of loyalty and devotion to the Museum is appreciated.

A better era is anticipated. Nothing in the past has had a more vital relation to the work of the Museum than the enactment by Congress, on March 4, 1923, of the classification act of 1923, for a more adequate pay schedule for the civilian employees of the Government, with provisions for equal pay for equal services regardless of the department in which the service is rendered. This reclassification becomes effective on July 1, 1924, before which date much preliminary work has to be completed. The writer was appointed liaison officer for the Government bureaus under the institution. Tentative allocations of all the positions under the institution were made during the latter part of the year and submitted to the personnel classification board created to care for the matter.

The year just closed was the second under the operation of the Budget system of estimates and appropriations, and necessarily involved changes in many methods of planning and keeping accounts. Operating as it has had to do on practically the same appropriations for the past 10 or 15 years, the Museum has difficulty in making ends meet, and it is only by rigid economy and by the omission of many things that should be done that the year ends without a deficit.

The function of the National Museum as the depository of the collections belonging to the United States is being recognized more and more, resulting, near the close of the fiscal year, in the transfer to the Museum by the Treasury Department of the entire collection of numismatic materials which the Government, up to a few years ago, exhibited at the United States Mint in Philadelphia. Congress also reaffirmed this function of the Museum in accepting the sword of Maj. Gen. Richard Montgomery of the Continental Army, given to the Nation by Miss Julia Barton Hunt, by directing that it be deposited in the National Museum.

At the annual meeting of the American Association of Museums in Charleston in April, 1923, the financial prospects were such that

arrangements were made for the establishment of headquarters in the National Capital, with a salaried director and secretary, Prof. Charles R. Richards and Mr. Laurence Vail Coleman, respectively. The National Museum gave support to the movement by permitting the association to have its offices in the Arts and Industries Building. Toward the end of the year headquarters of the association were accordingly established on the third floor of the northwest pavilion of that building. Professor Richards is spending his first year on leave in order to make a survey of European museums, and Mr. Coleman is in charge as acting director.

Three small rooms off the foyer in the Natural History Building, which have been held exclusively for use of temporary loan exhibits—usually in connection with gatherings in the auditorium—were this year assigned to the department of biology for the display of the animals of the District of Columbia. These collections, which for lack of room had been scattered in various halls or stored away, are now brought together and made available for students, amateurs, and school children of Washington.

In the Arts and Industries Building a new exhibition hall was prepared and opened to the public during the year, being a small room on the second floor of the southeast range. Here is shown an attractive display of historical relics received from the Military Service Institution, including the famous horse owned by Gen. Phil Sheridan.

BUILDINGS AND EQUIPMENT

The National Museum, in its own buildings and in the Smithsonian Building, occupies an aggregate floor space of over 670,000 square feet, or over 15½ acres, with roof area of approximately 5¾ acres, and some 2,000 windows. The upkeep is necessarily considerable, especially when it is recalled that the Smithsonian Building has been erected nearly 70 years, the Arts and Industries Building about 43 years, and the so-called South Shed about 25 years. The other structures are more recent, the Natural History Building being about 14 years old and the Aircraft Building about 6. Most of the space is used for exhibition purposes and must at all times be kept in good repair and in sightly condition. Constant vigilance is necessary to properly maintain these buildings within the appropriation allotted for the purpose, and it is only by strict economy that the present satisfactory results are accomplished.

Early in the year an emergency arose, namely, the falling of large pieces of plaster from the ceiling under the dome of the rotunda in the Arts and Industries Building, which necessitated the expenditure of 40 per cent of the entire appropriation provided for the maintenance of the buildings.

In the Natural History Building the most extensive repairs consisted of painting the east and west hall attics, the watchmen's room on the first floor, and tin gutters of roof, and the replacing of worn-out down spouts. The water table outside this building and the roadways on the south, east, and west sides of it were repaired. Measurements made this year show that the movement of the keystones of the stone arches in the rotunda has been but very slight. Observations and measurements will, however, continue to be made at intervals of a few months. The most important item in the Smithsonian Building was the repairing of a broken metal finial on top of the tower at the northwest corner of the main building.

Through the courtesy of the Commissioners of the District of Columbia and the cooperation of the fire department, the exterior walls of the Natural History Building were thoroughly washed in August, 1922, materially improving the appearance of the building. In attempting to get water for this purpose, the fire department discovered that all of the fire hydrants in the Smithsonian Park were in bad condition and of an antiquated type, leaving the buildings practically unprotected in case of fire. The District Commissioners called the attention of the Institution to the necessity of installing new hydrants and of adding to their number. An estimate to cover the installation of four new fire plugs in the Smithsonian Park was included in the estimates submitted by the Institution to the Bureau of the Budget in September, 1922. The estimate failed to receive favorable action, but will be again submitted for consideration. The fire plugs in all the buildings and the fire hose are tested regularly.

As usual, the power plant was not operated during the summer, a commercial company supplying the light and power required. While the plant was shut down the old feed-water heater, which had been in use ever since the plant was first put in operation, was replaced by a new Cochran open feed-water heater and meter, effecting a marked saving in the consumption of fuel. During the year 3,052 tons of bituminous and 15.5 tons of stove coal were consumed. Heat was supplied the buildings in the Smithsonian group, including the Freer Building, from October 9, 1922, until May 19, 1923. The total electric current generated was 376,293 kilowatt-hours. The electric load was greatly increased by the opening of the Freer Building to the public, near the close of the year, so that on dark and cloudy days it is greater than can be safely carried on the cables leading into the Natural History Building from the lines of the Potomac Electric Power Co. Additional cables will have to be installed to take care of this increase. The ventilation plant in the Freer Building was operated in the usual manner during the winter and up to the time the building was opened to the public, since which time the speed of the fans has been materially increased, to

provide the additional air necessary for properly ventilating the galleries. The result obtained by the system has been more satisfactory than was anticipated. While the temperature of the galleries has been somewhat high on extremely hot days, the circulation of air was sufficient to produce the necessary cooling effect in spite of the fact that no help was gained from the air washers.

The ice machine in the Natural History Building produced 279.6 tons of ice. The plant is gradually growing less efficient from year to year. An item covering the purchase of a new ice machine was included in the estimates for appropriations submitted to the Bureau of the Budget.

COLLECTIONS

The total number of specimens acquired by the Museum during the year was approximately 217,611, about 60 per cent as many as received during the preceding year. The value of the yearly increment can not, however, be appraised from numbers only. Many of the acquisitions this year are exceptionally valuable, either scientifically, as types and as representatives of new species and new localities, or because of great intrinsic worth. Additional material to the extent of 1,155 lots, mainly geological, was received during the year for special examination and report, a service of which the practical value was demonstrated during the World War.

The distribution of duplicates, mainly to schools and colleges for educational purposes, aggregated 9,131 specimens properly classified and labeled and 100 pounds of material suitable for blow-pipe analysis. These distributions were about equally divided between the regular sets of specimens previously prepared for shipment and those specially selected to meet particular needs. Nearly 35,000 duplicate specimens, mainly botanical and geological, were sent out in exchange, in return for which much desirable material was received. Over 12,000 specimens were lent to specialists for study on behalf of the Museum and otherwise.

Anthropology.—In anthropology the more important additions were a carved stone figure from the Makah Indians, showing a mastery of expression by the artist; casts of the La Quina and Obercassel skulls and skeleton; a noteworthy Chinese harvest bell of gilt bronze; a superior stone collar from Porto Rico; a series of archaeological specimens from Haiti; an ethnological collection from Formosa; an ancient stone pipe from Kentucky with remarkable incised decorations; and casts of the busts of the heretic Pharaoh, Amenophis IV and his queen, and a statuette of the latter.

Biology.—While the number of biological specimens received during the past fiscal year falls short of that of some of the previous years, there is no cause for alarm, as the scientific value of the col-

lections compares favorably with and probably exceeds that of the average.

No single collection stands out prominently, except perhaps the Evezard collection of recent mollusks, which was purchased and presented to the Museum by the late John B. Henderson. Another collection of great scientific interest is the series of Opalinid ciliate infusorians prepared by Professor Maynard M. Metcalf, of Oberlin, Ohio, which forms the basis of his monograph published during the year by the Museum as its Bulletin No. 120. The most significant feature of the year's accessions is the fact that some of the more important ones are from China, as a result of deliberate efforts at improving systematically the study material from the Palearctic region which is of such a fundamental importance for a full understanding of our North American fauna.

This tendency toward a more conscious development of the weak portions of our collections was made possible by the explorations now on the way in China undertaken by friends of the Museum, such as Mr. Charles M. Hoy's trip financed by Dr. W. L. Abbott, and Mr. A. de C. Sowerby's by Col. Robert S. Clark. Rev. D. C. Graham's explorations in the Province of Szechuen were also fruitful of scientifically valuable material, while an expedition recently sent into the field by the National Geographic Society under the leadership of Mr. Frederick R. Wulsin holds great promise for the future. Many important gaps in our South American collections were also filled by Dr. Hugh M. Smith as a result of his expedition to Uruguay. Dr. W. L. Abbott's visit to the Dominican Republic added materially to our botanical and herpetological series. Secretary Walcott's explorations in the Canadian Rockies, as well as Dr. Paul Bartsch's trip to the West Indies, and that of Dr. Leonard Stejneger to the Commander Islands were also productive of desirable material. The botanical expedition to Colombia by Dr. F. W. Pennell and Mr. Ellsworth P. Killip, undertaken in cooperation with the Philadelphia Academy of Natural Sciences, the New York Botanical Garden, and the Gray Herbarium of Harvard University, brought home one of the largest and most important plant collections ever obtained in that country. Dr. William R. Maxon had not returned from Central America at the end of the fiscal year.

The Australian mammal exhibit has been further strengthened by the addition of several species, and a Malay tapir was incorporated in the Oriental region exhibit. Several other large mammals were likewise mounted and placed on exhibition, among which the gorilla mounted by Brown and Aschemeier from a specimen collected by the latter a few years ago while attached to the Collins-Garner Expedition to French Congo, deserves special mention. Good progress

was made in the arrangement and cataloguing of the study series, which are described as in excellent condition.

The research work of the staff has continued unabated and several important manuscripts were brought to a close or nearly finished during the year. A large number of smaller papers were published as a result of the year's work, but the great majority of the published results date further back, partly due to the difficulties in obtaining speedy publication, partly because their preparation extends over a period of years. Some very important systematic works done by scientists not members of the staff, but based on Museum material, were published during the year as Bulletins No. 100, vol. 5, and Nos. 120 and 123.

Loans of specimens to scientific institutions and individual investigators have been made on the usual liberal scale. Duplicates distributed to high schools, colleges, institutions, etc., aggregated 3,545 specimens, of which 1,490 consisted of mollusks in 10 prepared sets and 608 fishes in 8 sets. Exchanges to the number of 28,693 were sent out, of which 2,491 were zoological and 26,202 botanical.

The total number of specimens of animals and plants now in the national collection is estimated to exceed 7,000,000, of which 1,150,000 are plants.

Geology.—Although accessions in the department of geology are smaller in number than in the year previous, a considerable increase in individual specimens and in their scientific value is to be noted.

The paleontological collection of the late Orestes St. John, consisting principally of fossil fishes, many of them types, adds material of incalculable value to the specialist who may take up the study of this group, and Dr. Frank Springer, who made this donation, has earned the thanks of future workers in thus placing it where it will always be available. Another most notable accession is the residuary portion of the collection of the late R. D. Lacoë, of Pittston, Pa., presented by his heirs. This is estimated to contain not less than 10,000 specimens, mainly fossil plants, with some invertebrates and vertebrates, from many localities in this and foreign countries, and from various geological horizons. Supplementing the collection is Mr. Lacoë's paleontological library comprising, it is estimated, at least 2,000 volumes and an equal number of pamphlets. Mrs. Coonley Ward generously donated the residuary portion of the meteorite collection of her husband, the late Prof. H. A. Ward. This is of value not so much in adding new meteorites as in furnishing material for study and exchange. Thirteen additional accessions of meteorites, mostly new to the collections, are recorded, received chiefly through exchanges.

Continued activities of Mr. Victor C. Heikes have resulted in the acquisition of the most interesting of the recent additions to the economic collections.

The division of mineralogy has benefited largely through exchanges. A most important acquisition is a portion of a large boulder of jade received from Col. W. B. Thompson, and an unusually fine specimen of crystallized descloizite from southwest Africa, acquired through Ward's Natural Science Establishment. Other exchanges resulted in adding upward of 60 pieces new to the collection. Several cut gems of unusual quality and size were purchased through the Chamberlain endowment fund.

The continued acquisition of foreign paleontological material is to be noted. Chief among the contributors are Dr. E. O. Ulrich, who made collections in northern Europe; Mr. Stephen R. Capps, in Palestine; various oil companies and private collectors in Mexico, Central and South America; Mr. Edwin A. Walford, of Banbury, England; and various universities and institutions in Europe.

Research work has formed an important part of the department's activities during the year, and assistance has been furnished to numerous schools and students, chiefly through the distribution of materials needed in their studies. The records show that 81 educational institutions, chiefly high schools and small colleges, have been given such assistance.

Textiles, wood technology, organic chemistry, foods, and medicine.—The collections under the supervision of the curator of textiles, which, besides textiles, embrace wood technology, foods, organic chemistry, and medicine, were increased by many gifts and by transfer and loan of property from other Government bureaus, amounting to over 2,000 objects. The most important of these are as follows:

A large series of specimens of pyralin, bakelite, condensite, and cellulose acetate, showing the manufacture and use of these products of modern chemical industry as substitutes for such natural raw materials as ivory, bone, horn, tortoise shell, amber, etc., the supplies of which are growing scarcer every year; and a set of pneumatic bicycle tires made in 1891 and believed to belong to one of the earliest types used. There were added by gift beautiful specimens of silks, woolen fabrics, and mohair upholstery textiles contributed by American manufacturers to show the progress of textile industries in this country.

To the collections arranged to show the importance of wood and the industries based upon the use of that raw material, there were added wonderfully well preserved specimens of the ancient cypress wood brought to the surface during the excavation for the foundation and basement of the new Walker Hotel, Washington, and be-

lieved to be over 30,000 years old; an exhibit showing the manufacture of double-tipped matches; and another pointing out the ravages of the white pine blister rust and methods for its control.

The collections in the division of medicine were enlarged by a large collection of Italian hospital supplies of the type used in the World War and carried as field equipment by the Italian troops; specimens showing the use of chaulmoogra oil derivatives in the treatment of leprosy in the leper settlement of Molokai, Hawaii; several ancient surgical instruments and medical manuscripts; and a portrait in oil of Dr. Crawford W. Long.

Mineral and Mechanical Technology.—The divisions of mineral and mechanical technology had the experience of adding more objects to their collections within the year than in any single year since their inception and almost wholly as a result of their own efforts. Practically every section within the divisions shared in this increment, but chiefly the sections devoted to mechanical communication, general mechanical engineering, coal-products industries, land transportation, and aerial transportation. The objects acquired for the section of communication will now make it possible to visualize the developments of methods of communication from those of smoke and fire to those of wireless telegraphy, with all of the essential intermediate steps. To the mechanical engineering collection there was added a series of models made in the divisions' workshops illustrating mechanical principles and the fundamental elements and devices used in machines. The subject is by no means covered by this series, which represents simply the beginning of a new activity possessing valuable educational possibilities. To the coal products industries section there was added a model illustrating the manufacture of coal gas and carburetted water gas. With this addition the divisions have covered fairly completely the fuel situation both in the home and in industry. In other sections of the divisions the additions to the collections tend toward a rounding out of individual subjects. Thus there were added several models of aircraft; a locomotive model; a boat model, and an automobile. The electrical engineering collections were enhanced by a working model of the Ford automobile ignition system which admirably illustrates the principle of induction as applied to electric current generation, a principle which Joseph Henry independently observed and announced about the same time as the accredited discoverer, Faraday.

The divisions' cooperative educational work, particularly that with the State of Pennsylvania, became more firmly established through the preparation by Mr. S. S. Wyer, associate in mineral technology, of the book "The Smithsonian Institution's Study of Natural Resources Applied to Pennsylvania's Resources." Copies of the book were distributed free to school teachers throughout Pennsylvania

designated by the board of education and used in certain fitting courses of the grade schools. One of the interesting reactions resulting from this work was the assistance rendered by Mr. Wyer to the city of Erie, Pa., in an intensive educational campaign organized by the local chamber of commerce in an endeavor to conserve the city's natural gas supply, which is rapidly declining, due largely to preventable wastage.

Graphic Arts.—The 1,146 specimens assigned to this division covered a wide range, materially exceeded in number those received the preceding year, and brought the total number of specimens in the division up to 22,936. Almost the beginning and the latest development of type composition were represented in the year's accessions by a leaf of the Gutenberg Bible, one of the first books to be printed from movable type, and examples of the monotype system of composing and casting justified lines of single type. Other important acquisitions included a newspaper exhibit; specimens of bookbinding; a unotype typesetting machine, wood-block prints and etchings by Helen Hyde; 50 proofs of etchings, aquatints, wood-block prints, lithographs, etc., the gift of 24 contemporary artists; Woodville Latham's motion picture projector of 1895; notable additions of pictorial photographic prints and color collections in photography; and many additions supplementing and completing existing exhibits.

Seven loan exhibits, five in the graphic arts halls and two in the gallery devoted to the photographic section, brought the Museum collections in these lines prominently before the local and visiting public. Two collections of pictorial photographs were lent for exhibition elsewhere and, in furthering publicity outside of Washington, two traveling exhibits of about 100 specimens each were prepared illustrating the principal processes of the graphic arts. The first of these was shown in seven different cities and the second, prepared later in the year, was exhibited only in one city.

History.—During the past fiscal year the historical collections received, in addition to the normal increase along this line, two accessions of unusual size and importance and one of unparalleled intrinsic and scientific value. The first of these includes the large aggregation of antiquarian, costume, military, naval, and miscellaneous materials collected by Mrs. Julian James during a long period for deposit in the National Museum, which by the terms of her will have now become the permanent property of the Institution. This collection has already been described in previous reports, but its permanent acquirement by the Museum is worthy of special note. The second accession of unusual significance is a large collection of historical military materials deposited in the Museum by the Military Service Institution. The collection was assembled by this

society beginning at the time of its organization in 1878, and consists for the most part of swords, guns, pistols, flags, and miscellaneous relics of the period of the Civil War, but includes also relics of the former wars in which the United States has participated. Among the most notable objects in the collection are a bronze cannon captured from the British troops commanded by Maj. Gen. John Burgoyne at Saratoga in 1777; a mortar made by D. King of Philadelphia; a sword owned by Commodore Stephen Decatur, United States Navy, and the mounted figure of the war horse of Gen. Philip H. Sheridan.

The accession of unparalleled importance is one including the entire collection of numismatic material formerly exhibited in the United States Mint in Philadelphia, which, owing to the closing of this mint to the public, was transferred to the Museum by the Treasury Department in June, 1923. This collection includes a large number of ancient coins, a fair representation of medieval European coins, a very complete aggregation of modern European coins and commemorative medals, a large collection of the temporary coins of the period of the World War, and an exceptionally fine and large collection of United States coins, medals, and paper currency. While the acquirement of this collection by the Museum is most gratifying in that it adds such an aggregation of intrinsically valuable matter to the Museum collection, the most essential fact in connection with the transaction is the basis which it offers for the future development of the collection and the encouragement of the science of numismatics in the United States.

EXPLORATIONS AND FIELD WORK

It is hoped that the falling off in biological exploration noted in recent reports has reached its lowest ebb during the present year, and that from now on a turn of the tide may be expected. With this possibility in view plans and problems for future biological explorations and expeditions have been outlined, preparing the Museum to take the greatest possible advantage of the hoped-for improved conditions. The central idea proceeds from the fact that the early biological problems and research of the Museum naturally related to the fauna and flora of North America, especially that part opened up by the War with Mexico and the explorations for railroad lines to the Pacific coast. The necessity of working up this material was naturally paramount. With the purchase of Alaska a hitherto unexplored territory on this continent naturally attracted the attention of the National Museum, especially since the early activities in Alaska were almost exclusively investigated by the Federal Government with the result that nearly all the material collected

there came to Washington. So intensive was this study of the native fauna, especially that of the vertebrates, that within a comparatively short time North America, from a taxonomic point of view, was better explored and better known than any other part of the world, Europe itself not excepted. At the time these intensive studies began North America was regarded as one of the primary zoogeographical divisions of the world, coequal with South America, the oriental region, Africa, and the Europe-North Asian region, also known as the palearctic region. Later on considerable collections from the Pacific coasts of northern Asia and from Europe found their way into the National Museum. It was then seen that the North American fauna, at least that part which occupied the more temperate portions of the continent northward, is most closely related to the palearctic fauna of temperate Asia and northward, and it was realized that the dominant constituency of the North American fauna actually had its origin in the Old World. Here then is a whole series of closely related problems seeking solution in Asia and Europe. The circumstance that the United States Biological Survey has gradually taken over to a great extent the restricted North American field for still more refined cultivation serves to stimulate the interest of certain of the larger divisions of the National Museum in the palearctic region. The Museum has already made a good start in that direction. It has excellent collections in many lines of the palearctic fauna. Its collection of European mammals is one of the most comprehensive extent. It has excellent series of birds, reptiles, and batrachians from Japan, Korea, and Kamchatka in eastern Asia, besides a respectable representation in other classes. It has also important material collected by the Lyman-Hollister expedition to the Altai region some years ago, and the Koren-Avery expedition to the mouth of the Kolyma.

It is, therefore, with special gratification that attention is called to the work now in preparation and partly in progress for the biological exploration of China in the interest of the National Museum. The field work by Arthur de C. Sowerby, the expense of which is most generously met by Robert S. Clark, which was started in the fall of 1921, has continued during the present fiscal year, and very material additions to our vertebrate collections have already resulted.

Of equal significance is the fact that Dr. W. L. Abbott, after the return of Mr. Charles M. Hoy from Australia, decided to send him to China to collect for the Museum. Mr. Hoy departed for his new field on December 15, 1922. Thus far no collections have been received, due to difficulties of transportation and the political situation which has placed obstacles in the way of reaching the final destination, but recent letters indicate that we may soon see tangible results of his efforts.

A third expedition in China, from which the National Museum is expected to derive great benefit, is that of the National Geographic Society, under the leadership of Mr. Frederick R. Wulsin who is already in the field.

In this connection should be mentioned the activities of Rev. D. C. Graham, who, located at Suifu in the Province of Szechuen, China, undertook an expedition to Mount Omei, from which the Museum received very important collections, especially insects, birds, and reptiles. He is planning to make an expedition to Tatsienlu, and possibly to Mupin, during the present summer, both localities of great zoological interest.

Dr. W. L. Abbott revisited the Dominican Republic in February and March, 1923, continuing his biological explorations of recent years. As his permit to collect birds was delayed until he was about to leave the country he only obtained the skin of one bird and saved its body in alcohol. His collections of reptiles and amphibians, however, were highly important, obtaining as he did a new species of frog, recently described by Miss Cochran as *Leptodactylus abbotti* from the specimen collected by him. It is nearly related to the one from Porto Rico and establishes the genus as one definitely belonging to the Antillean fauna. He also collected about 600 plants in the southern part of the Samana Peninsula, which will doubtless prove as interesting as the previous collections obtained in the same region by Doctor Abbott, which have yielded a large number of new species.

In connection with the heredity experiments conducted by Dr. Paul Bartsch, under the joint auspices of the Smithsonian and Carnegie Institutions, it was found desirable to add several species of Cerions in order to exhaust the apparent possibilities that this group presents. For that reason Doctor Bartsch visited Porto Rico in May, obtaining a large number of specimens of the desired Cerion, as well as a large series of additional species. About 15,000 specimens were added to the Museum collection as the result of the trip.

Dr. Hugh M. Smith, associate curator in zoology, spent several months in South America, primarily for the study of the fur-seal and other fisheries of Uruguay, during which time he made extensive collections for the Museum in all branches, especially fishes, reptiles, and marine invertebrates. He sailed from New York on September 23, 1922, returning in January, 1923. The opportunity to collect in Brazil when the steamer stopped was improved, but the main collections were made in Uruguay, especially at the Lobos Islands. The collections form a most welcome addition to the Museum series, which were very deficient in material from the region visited.

During the spring of 1923 Mr. C. R. Aschemeier, one of the taxidermists, was given permission to accompany Mr. A. H. Fisher on an expedition to the lower Amazon River, Brazil, the understanding

being that Mr. Aschemeier should devote his time to making collections of the vertebrates for the National Museum, with particular reference to river dolphins and seacows. He left New York late in April and no collections have been received as yet.

Dr. William M. Mann, assistant custodian, section of Hymenoptera, undertook for the Department of Agriculture a trip to Mexico between January 19 and June 7, 1923, for the purpose of collecting and studying certain fruit flies. As far as possible general collections of insects were made and some reptiles and a few ethnological specimens secured. The material has not as yet been accessioned, but enough is known of it to prove its value, although owing to the extreme dryness of the season collecting was very poor. From Nogales he went down the west coast of Mexico as far as Tepic, making a 10-day side trip to Lower California in the district between Loreto and Comondú. Afterwards the States of Jalisco and Colima were visited and then a rather hurried trip was made to the Isthmus of Tehuantepec and in Chiapas as far as Tapachula. He returned by way of Laredo, Tex.

Secretary Charles D. Walcott's expedition to the Canadian Rockies was productive of valuable additions to the mammal collection, as already mentioned.

The botanical explorations during the year have added materially to the collections of the National Herbarium. Dr. W. L. Abbott's visit to the Dominican Republic has already been mentioned.

Mrs. Agnes Chase visited Europe from March until July, 1922, for the purpose of studying the grass collections in the herbaria at Vienna, Munich, Florence, Pisa, Geneva, Berlin, Leiden, Brussels, Paris, and London, and many type specimens of American grasses were examined. A large number of valuable specimens of grasses also was obtained for deposit in the National Herbarium, including fragments of many types and duplicates of early South American collections.

Dr. William R. Maxon, associate curator of the division of plants, left Washington in May, 1923, accompanying a party directed by Mr. O. F. Cook, of the United States Department of Agriculture, whose purpose is to investigate the rubber resources of Central America. At the time of preparation of this report the party was in Panama and it was expected that two months additional would be spent in Central America.

Dr. A. S. Hitchcock, custodian of the grass herbarium, left Washington in May, 1923, with the expectation of spending six months in Bolivia, Ecuador, and Peru, where he intends to devote particular attention to the study of grasses, but will also make collections of other groups of plants. The expedition is supported jointly by the United States Department of Agriculture, New York Botanical Garden, and Gray Herbarium.

Dr. Charles E. Resser, under the auspices of the United States Geological Survey, accompanied Dr. E. O. Ulrich in an investigation of the Cambrian and Ordovician rocks of the Valley of Virginia during May, 1923, and secured important stratigraphic collections. Dr. Ulrich with his assistant, Mr. R. D. Mesler, continued field researches during the month of June, studying various sections of the Appalachian Valley in eastern Tennessee. During his trip to the International Geological Congress at Brussels in the summer of 1922, Doctor Ulrich visited important Paleozoic localities in various European countries and presented to the Museum all of the material collected.

While traveling in Europe in the summer of 1922, Miss Jessie G. Beach was detailed to study collections in various museums, and to consult with European scientists regarding matters of interest to the Museum. Miss Beach visited museums in France, Italy, Germany, Belgium, England, and Scotland, listing and sketching various type specimens of unusual interest, and studying methods of installation and labeling.

Mr. C. W. Gilmore, under the auspices of the Museum, made a trip to Roy, N. Mex., to investigate a reported discovery of *elephas* remains. The specimen proved to be valueless for museum purposes, and from that standpoint the trip was a failure. Mr. N. H. Boss made several short collecting trips to the Miocene deposits along Chesapeake Bay in search of fossil remains. As in previous years these trips were productive in the recovery of well-preserved cetacean remains.

Late in the fiscal year Mr. Gilmore and Mr. Boss were detailed to excavate remains of dinosaurs in the Dinosaur National Monument, Utah, an undertaking which has long been awaiting a favorable opportunity for its consummation.

Assistant curators Foshag and Shannon on their own initiative made a brief trip to old copper mines in Carroll County, Md., a district which despite its proximity to Washington was practically unrepresented in the collections. A large suite of copper and iron ores and associations was secured. A day was likewise spent at the diabase quarry near Belmont Park, Va. So much material of interest was found that Mr. Shannon conducted the Washington Mineralogical Society over the ground on their annual field trip. The specimens collected have been turned over to the Museum. The limestone quarry at Leesburg, Va., was also visited and interesting mineralogical material secured.

Investigations by Miss Frances Densmore among the Yuma Indians of Arizona and some tribes in northern Mexico for the Bureau

of American Ethnology brought to the Museum a collection of desirable ethnologica.

The third year of the exploration of ancient Pueblo Bonito, to which the National Geographic Society has devoted \$75,000, under Neil M. Judd, the curator of American archeology, was productive of a number of specimens now deposited in the Museum. The journeys of Dr. Aleš Hrdlička to Brazil and Europe resulted in enriching the collections of the division of physical anthropology. In June Mr. Matthew W. Stirling, of the division of ethnology, carried on an exploration of several ancient villages at Mobridge, S. Dak., and collected a valuable series of material for the Museum.

For several other important expeditions in which the Museum was interested see under Researches and Explorations in the report of the secretary, page 6.

MEETINGS, CONGRESSES, AND RECEPTIONS

The auditorium and adjacent council rooms afforded accommodations during the year for 145 meetings, covering a wide range of subjects. An innovation this year was a series of free Sunday afternoon lectures arranged by the Woman's Welfare Association. Heretofore the auditorium has not been used on that day.

The governmental agencies taking advantage of the meeting accommodations, besides, of course, the Smithsonian Institution and its branches, included the Budget Bureau and the Public Health Service of the Treasury Department; the War Department and its Army Medical School; the Women's Bureau of the Department of Labor; the Bureau of Entomology, the Forest Service, and the Federal Horticultural Board of the Department of Agriculture. The scientific and other groups included the National Academy of Sciences, the National Association of Postmasters of the United States, the National Committee on Prisons and Prison Labor, the National Association of Travelers Aid Societies, the National Conference of Social Work, the National Consumers' League, National Amateur Athletic Federation of America, the National Medical Association, the National Baird Memorial Committee, the Garden Club of America, the Girl Scouts, World's Dairy Congress Association, the American Association of Museums, Women's Welfare Association, the American Horticultural Society, the Anthropological Society of Washington, the Archaeological Society of Washington, the Art and Archaeological League of Washington, the Audubon Society of the District of Columbia, the Washington (D. C.) Chapter of the Wild Flower Preservation Society of America, the Entomological Society of Washington, the Federal Photographic Society, the Shakespeare Society of Washington, the School of Foreign Serv-

ice of Georgetown University, the American University, Howard University, the Garden Club of Washington, the Southern Society of Washington, and the Reserve Officers' Association of the District of Columbia.

At the Twentieth International Congress of Americanists at Rio de Janeiro, Brazil, August 20 to September 3, 1922, the Institution was represented by Dr. Walter Hough, head curator of anthropology in the Museum, and Dr. Aleš Hrdlička, curator of physical anthropology in the Museum, who served also as delegates on the part of the United States Government. Another member of the Museum staff, Dr. E. O. Ulrich, associate in paleontology, represented the Institution at the Thirteenth International Geological Congress meeting in Brussels, Belgium, August 10 to 19, 1922. The Museum was also represented at the eighteenth annual meeting of the American Association of Museums, held in Charleston, S. C., April 4 to 7, Mr. F. L. Lewton and the writer serving as delegates.

The Museum was the scene of several receptions. On the evening of December 19 the halls of the Museum assigned to the National Gallery of Art were opened for a reception following a lecture in the auditorium under the auspices of the Anthropological Society of Washington and the Archaeological Society of Washington. Opportunity was thus afforded for inspecting the collection of Chihuahua pottery belonging to the latter society. On January 9 the Archaeological Society and the Art and Archaeological League of Washington held a reception in the National Gallery of Art following an evening lecture by Count Byron Kuhn de Prorok, with a first view of a rare collection of antique jewelry recently lent to the society by one of its members, Mr. Kurt Walter Bachstitz, of The Hague. Another large reception was that to the National Academy of Sciences on the evening of April 23, in honor of Dr. W. W. Campbell. This followed a lecture in the auditorium by Doctor Campbell.

The exhibition halls on the first floor of the Natural History Building were the setting for a conversazione on the evening of February 3, as a part of the program in celebration of the centenary of the birth of Spencer Fullerton Baird, the second secretary of the Smithsonian Institution. The Marine Band furnished music during the evening. A meeting of Girl Scout leaders in the auditorium on the evening of April 25 was the occasion for opening all the exhibition halls in the building from 6.30 to 11 p. m. to enable the Girl Scouts, their leaders, parents, and friends to view the collections.

MISCELLANEOUS

The number of visitors to the Natural History Building during the year aggregated 508,518; to the Arts and Industries Building, 259,542; to the Smithsonian Building, 95,168; and to the Aircraft

Building, 42,904. The national collections in the Natural History Building are accessible to the public every day in the year, Sundays as well as week days. Owing, however, to the limited appropriations for the maintenance of the Museum, the other buildings are not open on Sundays.

The Museum published during the year 10 volumes and 42 separate papers. The former comprised the Annual Report of the Museum for 1922; volumes 60 and 61 of the Proceedings; Bulletin 100, volume 5; Bulletins 120, 121, 122, 123, 124, and 126. The separates included 1 bulletin article; 4 papers in the series, Contributions from the United States National Herbarium; 5 papers from volume 61, 21 papers from volume 62, and 11 papers from volume 63 of the Proceedings. The distribution of volumes and separates to libraries and individuals on the regular mailing list aggregated 63,869 copies besides 8,660 copies supplied in response to special applications.

The Museum library, as one of the libraries administered under the direction of the Smithsonian Institution, enjoys the close cooperation of its associated libraries and in turn contributes substantially toward the general library activities. Much has been accomplished during the year toward better library service. The long-needed subject catalogue has been started, and at the close of the year 4,400 cards had been made and arranged. The arrangement of cards from the Concilium Bibliographicum distributed since the World War is well under way, and progress is being made in the reclassification and shelving of the technological collections. Work has, however, suffered from a lack of funds for binding and renovating and from a vacancy in the staff during eight months of the year. The receipts for the year numbered 1,489 volumes and 2,796 pamphlets, bringing up the total of books and other material in the library to 160,560 titles. The number of loans made was 9,220, of which 5,191 were to the sectional libraries.

The death of John B. Henderson, a Regent of the Smithsonian Institution, on January 4, 1923, deprived the Museum of a valued friend, a constant contributor and an indefatigable worker on its collections. The members of the scientific staff and other employees of the Museum and Institution gathered in the auditorium on January 8, 1923, to pay respect to their colleague and adopted resolutions expressing their deep sense of loss. Doctor Walcott presided and brief addresses were made by Doctor Walcott, Dr. W. H. Dall, Dr. Leonhard Stejneger, and Dr. Paul Bartsch.

Respectfully submitted.

W. DE C. RAVENEL,

Administrative Assistant to the Secretary in charge,

United States National Museum.

DR. CHARLES D. WALCOTT,

Secretary, Smithsonian Institution.

APPENDIX 2

REPORT ON THE NATIONAL GALLERY OF ART

SIR: I have the honor to submit herewith the report on the activities of the National Gallery of Art for the fiscal year ending June 30, 1923.

The third year of the existence of the National Gallery as a separate administrative unit of the Smithsonian Institution has witnessed substantial advance in a number of directions, although additions to the art collections have fallen below those of several previous years. The activities of the gallery continued in most respects in directions corresponding with those of the two preceding years, the energies of the limited staff being devoted largely to the receipt, installation, and care of the collections; to completing the records and labeling; and to the preparation and publication of matter intended to aid in awakening an interest in the welfare of the gallery, and more especially in making known the vital importance of a gallery building.

An illustrated lecture prepared by the director, with the purpose of making the gallery and its needs better known to the public, has been widely presented. One copy with 75 lantern views, illustrating the gallery's collections, is in the hands of Mrs. J. W. Summers, of Walla Walla, Wash., who has associated with her Mrs. Henry Osterman, and has been utilized largely under the auspices of the Federation of Women's Clubs, principally in the State of Washington. A second copy (with seven additional slides), intrusted to Miss Leila Mechlin, secretary of the American Federation of Arts, and utilized under the auspices of that important organization, is being very generally presented in the smaller cities and towns of the United States; and a third copy (with 83 slides), placed in the hands of Mrs. Rose V. S. Berry, chairman of the fine arts department of the Federation of Woman's Clubs, is being featured at the meetings of that club throughout the country.

A recent act of Congress authorizes the raising of funds for the erection of a national gallery building in the following language: "The Regents of the Smithsonian Institution are authorized to prepare preliminary plans for a suitable fireproof building with granite fronts for the National Gallery of Art, including the National Portrait Gallery and the history collections of the United States National

Museum, said building to be erected when funds from gifts or bequests are in the possession of the said Regents, in sections or completely on the north side of the Mall between the Natural History Building, United States National Museum, and Seventh Street, leaving a space between it and the latter of not less than one hundred feet and a space of not less than one hundred feet between it and Seventh Street, with its south front on a line with the south front of the said Natural History Building.

A two-page leaflet on the national gallery has been issued, which, like the recent leaflets on the Smithsonian Institution, is to have a wide distribution. It is intended to bring forcibly to the attention of the public the great need for a separate building to house the national art collections.

Detailed information regarding the growth of the gallery within the institution and as a feature of the United States National Museum may be found in Bulletin 70 of the National Museum, and its subsequent activities are recorded in the annual reports of the institution and Museum and in the annual reports of the gallery for the years 1921 and 1922.

In two articles prepared by the director and published in art journals during the year attention is called to the growth of the national gallery and to the great need for a gallery building. The first, under the title "The Story of the National Gallery of Art," appeared in *Art and Archeology* for June, 1923. The story of the National Gallery of Art from its beginning nearly a century ago is the record of the prolonged struggle of the art idea for national recognition for a place in the serious consideration of the American people, and it is to be regretted that to-day, although art institutions are springing up on all hands, art has slight national recognition beyond the attention necessary to the care and display of the art treasures acquired by gift and bequest. For nearly a century the Smithsonian Institution has harbored the dream of a gallery of art, but art has been in the shadow of diversified scientific activities and in the deeper shadow of the all-absorbing material interests of a rapidly developing Nation. To-day the conditions are far from satisfactory. Growth of the collections through gratuitous contributions, even, is embarrassed by the almost complete exhaustion of space for the reception and display of all save accessions of very limited extent, and the problem before the institution, and certainly with equal insistence before the American people, is "Shall America have a National Gallery of Art, or a National Museum of Art, that will give us a respectable place among the cultured nations of the world?" The story of the vicissitudes of the incipient, struggling national gallery is here presented with the view of making known a

great national shortcoming and stirring the pride of a people not accustomed to take a second or a third place in any field worthy of their ambition.

The second, with the title "Shall America Have a National Gallery of Art?" was published in *The American Magazine of Art* for July, 1923. This article is a plea for recognition of the claims of the incipient national gallery upon the American people and seeks to determine and enlist the agencies that may be brought to bear upon the erection of a gallery building.

The great importance of prompt action becomes apparent when it is recalled that the failure to provide housing for possible additions to the national collections means a great annual loss to the national gallery—to the Nation. The yearly addition of art works between 1905 and 1920, the latter the date of the complete exhaustion of gallery space in Museum buildings, averaged upward of half a million a year, while the entire increase per year for the three years since the latter date has fallen below \$40,000. The loss to the gallery and to the Nation at this rate, would, in a score of years, amount to a sum equal to the erection of a building worthy of the name, and there can be little doubt that if a gallery building worthy of the name awaited the inflow of gifts and bequests, accessions would reach the substantial figure of half a million per year, as heretofore, or who shall say not twice that figure? Private owners, seeking a final resting place for their treasures, would doubtless, in many cases, prefer to be represented in a gallery belonging to the Nation, to all the people alike, than in any other. Our plea, then, the plea of the Smithsonian Institution, is not only a worthy but an urgent one, and is now made to all the people of the Nation, and for all the people of the Nation.

THE GALLERY COMMISSION

In 1921, the Regents of the Institution organized a commission which should devote its attention to the promotion of the gallery's interests in various directions, and the second annual meeting of this commission was held in the Regents' room of the Institution on December 12, 1922. The members present were: Daniel Chester French, chairman; W. K. Bixby; William H. Holmes, secretary ex officio; Gari Melchers; Charles Moore; James Parmelee; Edward W. Redfield; Charles D. Walcott, ex officio. At this meeting numerous important problems were considered and steps were taken to enlist national interest in the gallery and its development as an indispensable national institution.

The report of the secretary of the commission for the year was followed by reports of the standing, special, and subcommittees.

Attention was given to the previously much-discussed project of an important exhibition of portraits, official and lay, to be held in the gallery, but satisfactory arrangements for holding the exhibit in 1923 could not be made. The question of appealing to Congress for a building for art and history was considered and discussion took place as to the feasibility of having the building project included in the program being formulated by Congress for prospective public buildings. Secretary Walcott brought to the attention of the commission the question of the advisability of an appeal to American institutions and to the American people for aid in the building project. Following a discussion of the Ranger bequest fund and its administration, the commission appointed a committee of three—Messrs. E. W. Redfield, Gari Melchers, W. H. Holmes—to look after the gallery's interests in the final disposition of the purchases made from this fund by the National Academy of Design.

With this meeting, the initial one year terms of three members of the commission—Herbert Adams, Gari Melchers, Charles Moore—expired, and the Board of Regents at its annual meeting, December 14, 1922, elected these persons to succeed themselves for the full term of four years.

The art advisory committee appointed at the last meeting of the Board of Regents, examined the several paintings and other works offered to the gallery as permanent accessions. The following were accepted:

“Signing of the Treaty of Ghent,” an oil painting by Sir A. Forestier, 1914. Presented by the Sulgrave Institution.

A cameo-cutter's outfit, consisting of wheel, dies, tools, etc., which formerly belonged to and was used by Louis Bonet, an engraver on fine stone. Presented by Paul W. Bartlett.

THE NATIONAL PORTRAIT COLLECTION

As announced in the report for last year, a number of influential citizens, desiring to preserve some pictorial record of the World War, organized a National Art Committee immediately after the close of the war, and arranged with a number of our leading artists to paint portraits of certain distinguished leaders of America and other allied nations in the war with Germany. The members of the committee as organized are: Hon. Henry White (chairman); Herbert L. Pratt (secretary and treasurer); Mrs. W. H. Crocker, Robert W. de Forest, Abram Garfield, Mrs. E. H. Harriman, Arthur W. Meeker, J. Pierpont Morgan, Charles P. Taft, Charles D. Walcott, and Henry C. Frick (since deceased).

Under this arrangement, 21 portraits were painted and assembled in the national gallery during the month of May, 1921. Later these

were turned over to the American Federation of Arts for purposes of public exhibition. Before their final return to their place in the national portrait gallery, they were exhibited as follows:

1920-21:

Providence, R. I.-----	Rhode Island School of Design.
Philadelphia, Pa-----	Pennsylvania Academy.
Washington, D. C-----	National Gallery of Art.
Princeton, N. J-----	Princeton University.
New Haven, Conn-----	Yale University.
Boston, Mass-----	Boston Museum.

1921-22:

Rochester, N. Y-----	Memorial Art Gallery.
Cleveland, Ohio-----	Cleveland Museum.
Williamstown, Mass-----	Williams College.
Amherst, Mass-----	Amherst College.
Buffalo, N. Y-----	The Buffalo Fine Arts Academy.
Cincinnati, Ohio-----	Cincinnati Museum.
Indianapolis, Ind-----	John Herron Art Institute.
Pittsburgh, Pa-----	Carnegie Institute.
Detroit, Mich-----	Detroit Museum.
Youngstown, Ohio-----	The Butler Art Institute.
Memphis, Tenn-----	Brooks Memorial Art Gallery.
St. Louis, Mo-----	City Art Museum.

1922-23:

Grand Rapids, Mich-----	The Grand Rapids Public Library.
Ann Arbor, Mich-----	The Ann Arbor Art Association.
Topeka, Kans-----	Art Department, Washburn College.
Madison, Wis-----	The Madison Art Association.
San Francisco, Calif-----	San Francisco Museum.
Sacramento, Calif-----	Kingsley Art Club.
Baltimore, Md-----	Baltimore Museum of Art.

That the gift of these portraits might be distinctly national in character, it was decided that a group of two or more, financed by the art patrons of any city, should be inscribed as presented to the Nation by that city and that a representative of that city should become an honorary member of the National Art Committee. It was further decided that a tablet or other permanent record in the gallery should bear the names of the National Art Committee, including the chairmen of all local committees, and that there should be a record of the name of each subscriber to the purchase fund.

The cities which, to date, have made presentations are as follows:

Chicago—Portraits by John C. Johansen, N. A. (1876-):

Field Marshal Sir Douglas Haig, commander in chief of the British Army on the Western Front, 1915-1919.

Marshal Joseph Joffre, commander in chief of the French Armies, 1915-1917. O. M. 1919. *

General Amando Diaz, commander in chief of the Italian Armies, 1917- .

Cincinnati—Portraits by Douglas Volk, N. A. (1856-) :

His Majesty Albert I (Leopold-Clement-Marie-Meinrad), King of the Belgians, 1909- , and commander in chief of the Belgian Armies.

Right Honorable David Lloyd George, Prime Minister and First Lord of the Treasury of Great Britain, 1916-1922.

General John Joseph Pershing, commander in chief of the American Expeditionary Forces in Europe, 1917-1919.

New York—Portraits by Edmund C. Tarbell, N. A. (1862-) :

Woodrow Wilson, President of the United States, 1913-1921.

General Georges Leman (Gerard Mathieu Joseph Georges), commander of the fortified town of Liege (its defender in 1914).

Marshal Ferdinand Foch, commander in chief of the French Armies, 1917- ; of the Allied forces, 1918- .

"Signing of the Peace Treaty, June 28, 1919," by John C. Johansen, N. A.

San Francisco—Portraits by Cecilia Beaux, N. A. :

Cardinal Desiré Josph Mercier, Archbishop of Malines, 1906-

Admiral Sir David Beatty, commander of the fleet and First Sea Lord of Great Britain; created First Earl Beatty, 1919.

Georges Clemenceau (Georges Eugene Benjamin), President, Council of Ministers of the French Republic, Prime Minister and Minister of War of France, 1917-1920.

The following portraits are still available for presentation by other cities. In case offers are not made it is assumed that the committee remains responsible for their final disposition :

Joan J. C. Bratiano (Bratianu), Prime Minister of Roumania and delegate to the Peace Conference, 1919, by Charles Hopkinson.

Nikola Pashich (Pasic), Prime Minister of Serbia and delegate from Yugoslavia to the Peace Conference, 1919, by Charles Hopkinson.

Prince Kimmochi Saionji, delegate from Japan to the Peace Conference at Paris, 1919, by Charles Hopkinson.

Right Honorable Sir Robert Laird Borden, Prime Minister of Canada, 1911-1920, by Joseph de Camp.

General Sir Arthur William Currie, commander of the Canadian Forces in France, 1917-1919, by Joseph de Camp.

Admiral William Snowden Simms, commander of the American naval operations in European waters, 1917-1919, by Irving R. Wiles, N. A.

Herbert Clark Hoover, United States Food Administrator, 1917-1919; chairman of the Supreme Economic Council, Paris, 1919.

Vittorio Emanuele Orlando, president of the Council of Ministers of Italy, 1917-1919.

The collection of 21 portraits was returned to the gallery by the American Federation of Arts on June 12, 1923, and was hung in the central hall of the ground floor in direct connection with the great body of exhibits pertaining to the war with Germany. On its return to Washington the collection was enriched by the three-quarter length portrait of Her Majesty Elizabeth, Queen of the Belgians, by Jean McLean (Mrs. John C. Johansen), the completion of which had been delayed.

ART WORKS ADDED DURING THE YEAR

GIFTS AND REQUESTS

Portrait of Miss Elizabeth Ellery Burge, by Thomas Mathewson, and portrait of Miss Jessie Jay Burge, by Abbott Handerson Thayer (1849-1921). "Permanent loan" (stipulated term), from the Misses Marie Louise and Jessie Jay Burge, of Warsaw, N. Y.

Two oil paintings: "Une Brave" and "An Alsatian Girl," by Miss Lucie Louise Fery. Bequests of the artist, through Mr. George H. Moffett, executor, Charleston, S. C.

"Wharf Scene" (oil), by Bertha E. Perrie. Gift of Miss Maude Burr Morris, Washington, D. C.

Mantel of carved white holly wood, with fireplace of pink Numidian marble, from the recently demolished residence of the late Benjamin H. Warder, 1515 K Street, Washington, D. C., Henry Hobson Richardson, architect (1838-1886). Gift of William White Wilson Parker, of Washington, D. C., and Mifflintown, Pa.

"Roosevelt Haunts, Early Autumn" (oil), by Emile Walters (1893-); awarded the William O. Goodman prize by the Art Institute of Chicago, 1921. Presented by an art collector, through Mr. A. Lawrence Kocher, of the Pennsylvania State College.

A list of the portraits presented by various cities through the National Art Committee, Hon. Henry White, chairman, to the National Portrait Gallery is given on page 49.

Portraits deposited by the National Art Committee and available for presentation by other cities are listed on page 50.

A Chinese carved ivory screen and 141 pieces of antique and modern porcelain, made in Saxony, Austria, Denmark, Holland, Germany, France, and Great Britain between 1790 and 1860, were added to his collection by the Rev. Alfred Duane Pell, D. D., of New York.

DEPOSIT BY THE SMITHSONIAN INSTITUTION

Bronze bust of Jeanne d'Arc, by Madame Berthe Girardet, gold medalist, Neuilly, France. Gift of Madame Girardet, the sculptor, through Mrs. John Jacob Hoff (Mrs. Grace Whitney Hoff), "to the American people in memory of what our soldier boys have done in France at a crucial time of need." Accepted by the Smithsonian Institution for deposit in the gallery.

The collection of 22 framed individual portraits and portrait groups in pastel, 70 portraits in all, of Federal and Confederate Veterans of the Civil War, painted by Walter Beck (1864-), 50 years after the battle of Appomattox, lent to the Smithsonian Institution on May 1, 1922, for a period of one year, through the agency of Mr. Walter Grant, became the property of the Nation by gift of

the artist at the expiration of the year, "to be cared for by the National Gallery of Art." A complete list of these portraits was given in last year's report.

Portrait in oil of Edwin McMasters Stanton (1814-1859), Secretary of War under President Lincoln's administration, by Henry Ulke (1821-1910). Presented to the institution by his granddaughter, Miss Sophy Stanton.

LOANS

The John Howard McFadden collection of 43 portraits and landscapes of the British school, left in trust to the city of Philadelphia; lent to the gallery by the trustees of the collection, Chief Justice Robert Von Moschzisker, of the Pennsylvania Supreme Court, Hon. George Wharton Pepper, United States Senator from Pennsylvania, and Justice Jasper Yates Brinton, court of appeals, mixed tribunals of Egypt. The will of Mr. McFadden directs that the trustees shall, pending the permanent housing of the collection by the city of Philadelphia, intrust the works to the Metropolitan Museum in New York or to a gallery of equal dignity. A catalogue of the McFadden collection, prepared by Harvey M. Watts, was published by the J. P. Lippincott Co. during the year. The artists represented, with titles of the paintings received, are as follows:

Richard Parks Bonington (1801-1828).

A Coast Scene, Normandy.

John Constable, R. A. (1776-1837).

The Lock.

Hampstead Heath: Storm Coming Up.

The Dell in Helmingham Park.

David Cox (1783-1859).

Going to the Hayfield, 1849.

John Crome ("Old Crome") (1769-1821).

Blacksmith Shop, near Hingham, Norfolk.

Woody Landscape, at Colney.

Thomas Gainsborough, R. A. (1727-1788).

Henrietta, Lady Rodney.

A Classical Landscape.

George Henry Harlow (1787-1819).

The Misses Leader.

The Leader Children.

Mrs. Weddell and Children.

William Hogarth (1697-1764).

The Assembly at Wanstead House.

The Fountaine Family.

John Hoppner, R. A. (1758-1810).

Mrs. Hoppner.

Sir Thomas Lawrence, P. R. A. (1769-1830).

Miss West (afterwards Mrs. William Woodgate).

- John Linnell, Sen. (1792-1882).
 The Refuge (or, The Storm), 1853.
- George Morland (1763-1804).
 Old Coaching Days.
 The Fruits of Early Industry.
 The Happy Cottagers.
- Sir Henry Raeburn, R. A. (1756-1823).
 Lady Belhaven.
 Master Thomas Bissland.
 Master John Campbell of Saddell.
 Colonel Charles Christie.
 Lady Elibank.
 Mr. Lawrie, of Woodlea, Castle Douglas.
 Alexander Shaw.
 Portrait of a Gentleman.
- Sir Joshua Reynolds, P. R. A. (1723-1792).
 Master Bunbury.
 The Right Hon. Edmund P. Burke, M. P.
- George Romney (1734-1802).
 Mrs. Crouch.
 Mrs. De Crespigny.
 Mrs. Finch.
 Lady Grantham.
 Lady Hamilton (Study Head).
 Mrs. Tickell.
 Rev. John Wesley.
 Little Bo-Peep.
- James Stark (1794-1859).
 Landscape with Cattle.
- George Stubbs, R. A. (1724-1806).
 Labourers; The Brick Cart, 1767.
- J. M. W. Turner, R. A. (1775-1851).
 Burning of the Houses of Parliament.
- Sir John Watson-Gordon, R. A. (1790-1864).
 Sir Walter Scott, Bart.
- Richard Wilson, R. A. (1714-1782).
 View on the Thames.

Collection of 14 British and Dutch masters, lent by Henry Cleveland Perkins, Esq., of Washington and New York, as follows:

- Sir William Beechey, R. A. (1753-1839).
 Portrait of a Gentleman.
- John Hoppner, R. A. (1758-1810).
 Portrait of a Boy.
- Sir Thomas Lawrence, P. R. A. (1769-1830).
 Henry, First Earl of Mulgrave.
- Ladbroke.
 A Cottage Scene.
- Michael Jansen Mierevelt (1567-1641).
 Portrait of a Dutch Lady.
- John Ople, R. A. (1761-1807).
 Portrait of a Girl.

Sir Joshua Reynolds, P. R. A. (1723-1792).

Frances, Countess of Clermont. (From collection of the Earl of Carlisle).

Salomon Ruysdael (1600-1670).

The Windmill.

Richard Wilson, R. A. (1714-1782).

Study of Ruins.

Study of Ruins.

Landscape.

Artist unknown.

Landscape with Cottage.

Attributed to Van Dyck.

Madonna and Child. (From the Duchess of Montrose Collection, Eng.).

Jan Victoors (1620-1672).

Portrait of a Dutch Girl. (Collection of the Princess Mathilde.)

Three oil paintings by E. Hodgson Smart (1873-): "The Portrait of my Mother," 1915; "The Madonna of the Blue Veil," 1918; and portrait of James A. Stearman, 1917. Lent by the artist; withdrawn before close of the fiscal year.

"The Sphinx" (oil painting), by Colonel George Raum, C. S. A., as it appeared when excavated by him in 1896. Lent by the artist, Berkeley, Calif.

Three oil paintings: "The Fortune Teller," by Antonio Allegri da Correggio (1494-1534); "The Queen," by Jacobo Robusti (Il Tintoretto) (1512-8 to 1594); "Death of Lucretia," by Guido Reni (called Guido) (1575-1642). Acquired by the late Hon. Hannis Taylor in 1887, during his sojourn in Spain as United States minister, and lent by Mrs. Hannis Taylor, Washington, D. C.

"Spectres of the North (Icebergs)," and "Shoshone Falls of Snake River, Idaho," by Thomas Moran (1837-). Lent by the artist, Santa Barbara, Calif.

Self portrait by the artist, James DeVeaux, of Charleston, S. C. (1812-1844), painted in Paris, 1836. Lent by Mr. Porter F. Cope, Philadelphia, Pa.

Main entrance to the Benjamin H. Warder residence designed by H. H. Richardson, from the Benjamin H. Warder residence, 1515 K Street NW., removed to make room for a modern office building. The stone is of Numidian marble and the wood white holly. Carving of the holly is by skilled workmen, assisted by students from Richardson's Boston office. Erected in 1885, and among the last houses designed by Richardson. Other houses by this master architect are the John Hay, the Henry Adams, and the N. L. Anderson residences in Washington. Richardson was born in New Orleans, the son of a southern planter; educated at Harvard and the Ecole des Beaux Arts, Paris; died 1886, aged 47 years. Lent by the Architects' Advisory Council, Horace W. Peasley, chairman.

Portrait of Richard Brinsley Sheridan, by Sir Joshua Reynolds. P. R. A. (1723-1792); lent by Ralph Cross Johnson, Esq.

Five paintings: Portrait of Admiral Holding Stevens, 2d, by Robert Hinckley; portrait of Mrs. Thomas Holding Stevens, his wife, artist unknown; portrait of Hon. Eben Sage, of Middletown, Conn., by Chester Harding; "Madonna," by Honario Mariari, favorite pupil of Carlo Dulci; "Madonna," by Carlo Mahratta. Lent by Mrs. Pierre C. Stevens, through Mrs. Frederick C. Hicks, Port Washington, Long Island, N. Y.

Portrait of Warren G. Harding, President of the United States, 1921-1923; by E. Hodgson Smart (1873-). Lent by the artist.

DISTRIBUTIONS

Loans have been withdrawn by their owners, as follows: "Christ in the Temple," by J. B. Tiepolo; "The Doctor's Visit," by Jan Steen; and "A Young Dutch Girl," by N. Drost; withdrawn by Ralph Johnson, Esq.

Portrait of George Washington, by Rembrandt Peale, and portrait of John V. L. Pruyn, by Charles L. Elliott; withdrawn by Hon. Charles S. Hamlin. (The Washington was returned before close of the year.)

Portrait of Henry Clay Ide, by Ossip Perelma; turned over to Mrs. W. Bourke Cockran by direction of Mr. Perelma.

Portrait of Dr. George F. Becker and of Mrs. Florence Becker, by Fedor Encke; portrait of Mrs. Sarah Carey Becker, by Waring; painting by a Japanese artist; "A Woodland Study" and "The Placid Potomac," by W. H. Holmes; "The Deer Pass" (steel engraving), by Landseer, and a bas-relief; withdrawn by Mrs. Florence Becker Forrester.

"Landscape," by N. Diaz; withdrawn by Dr. C. C. Galloway.

"The Madonna of the Blue Veil," "Portrait of My Mother," and portrait of James A. Stearman, by E. Hodgson Smart; withdrawn by Mr. Smart.

Don Giovanni Rilgas, attributed to Cimabue; withdrawn by Capt. Edgar Thompson, United States Navy.

LOANS BY THE GALLERY

The painting recently received through the Ranger fund, entitled "Tohickon," by Daniel Garber, N. A., was lent to the Art Institute, of Chicago, to be shown at their annual exhibition, November 2 to December 1, 1922. It has been returned to the gallery.

The portrait of Miss Ellen Day Hale, by Mrs. Margaret Lesley Bush-Brown, presented to the gallery by Mr. Arthur Hale, was lent to Mrs. Bush-Brown to be exhibited at the Art Alliance of Phila-

delphia from January 3 to 16, 1923. It has been returned to the gallery.

The portrait of Sir James J. Shannon, R. A., painted in London in Sir James's studio by Orland Rouland (1871-), was lent to Mr. Rouland to be included in an exhibit of his paintings in New York City, April 15-25, 1923. The painting has been returned to the gallery.

The portrait of Gen. George Washington, by Rembrandt Peale, belonging to Hon. and Mrs. Charles S. Hamlin, and the portrait of George Washington, by Charles Willson Peale, the property of Mr. John S. Beck, and recorded as loans to the gallery, were lent, by permission of their respective owners, to the Pennsylvania Academy of Fine Arts, Philadelphia, Pa., to be shown at the academy's exhibition of portraits by Charles Willson Peale, Rembrandt Peale, and James Peale, April 11 to May 9, 1923. These paintings have been returned to their places in the loan collection.

SPECIAL EXHIBITIONS

An exhibition of American handicrafts assembled and circulated by the American Federation of Arts was held in the gallery from November 1 to 25, 1922. It included jewelry, enamels, carved ivory, silver, pewter, iron, pottery, decorated china, batik and block-printed textiles, weavings, needlework, bookbinding, illuminations, book plates, designs for advertising, stained glass, wood carving, and lacquer, and consisted of 212 items, as shown by the catalogue prepared by Miss Elizabeth Neat and printed privately. The regents and secretary of the Smithsonian Institution extended invitations to an opening private view of the exhibit on the afternoon of Wednesday, November 1, and many persons attended.

A collection of antique Etruscan, Greco-Roman, and Byzantine jewelry, and ancient glassware, pottery, and a bronze statuette of Nyx (Night), dating from the seventh century B. C. to the eleventh century A. D., was exhibited in the gallery under the auspices of the Archaeological Society of Washington, Dr. Mitchell Carroll, secretary, from January 10 to April 23, 1923. This collection is the property of Mr. Kurt W. Bachstitz, of The Hague, Holland, by whom it was lent to the Archaeological Society. A reception by the society was held on the evening of January 9, when the members and friends assembled to hear the lecture by Count Byron Kuhn de Prorok on his recent excavations at Carthage viewed the collection.

The Chicago Tribune exhibit of 90 original architectural drawings, selected from over 200 designs submitted in the Chicago Tribune's \$100,000 architectural competition for their new \$7,000,000 administration building was held in the gallery April 19 to 21.

This competition engaged the talents of the best men in the architectural profession throughout the world, 22 nations being represented, and not only the prize design, by John M. Howells and Raymond M. Hood, associates, of New York (who became the architects of the building), but also those receiving other prizes and honorable mentions, were shown. The exhibit was placed on view by the Chicago Tribune in cities throughout the country at the chapters of the American Institute of Architects, fine art societies and art institutions, architectural schools, and universities, and was procured for the national gallery through the efforts of the Hon. Frederic A. Delano, Regent of the Smithsonian Institution.

THE HENRY WARD RANGER FUND

The paintings purchased during the year by the council of the National Academy of Design from the fund provided by the Henry Ward Ranger bequest, with the names of the institutions to which they have been assigned, are as follows:

Title	Artist	Date purchased	Assigned
20. The High Seas.....	Gordon Grant.....	Dec. 4, 1922	Art Association of Richmond, Ind.
21. A Morning in Summer.	Leonard Ochtman, N. A.	.....do.....	Albany Institute and Historical and Art Society, Albany, N.Y.
22. The Quiet Valley...	Guy Wiggins, A. N. A.	.....do.....	Rhode Island School of Design, Providence, R. I.
23. The Maumee River.	Carlton T. Chapman, N. A.	.....do.....	The Toledo Museum of Art, Toledo, Ohio.
24. Winds of Destiny...	Elliot Clark, A. N. A.	.....do.....	The Dayton Museum of Arts, Dayton, Ohio.
25. Sleep.....	Leon Kroll, A. N. A.	.....do.....	The City Art Museum of St. Louis, Mo.
26. By the Upper Lock.	John F. Follinsbee, A. N. A.	Apr. 17, 1923	Grand Rapids Art Association, Grand Rapids, Mich.
27. The Gift.....	Ernest L. Blumen- schein, A. N. A.	.....do.....	Fort Worth Museum of Art, Fort Worth, Tex.
28. Brooding Silence....	John F. Carlson, A. N. A.	.....do.....	Baltimore Museum of Art, Baltimore, Md.
29. Smugglers' Notch, Stowe, Vt.	Chauncey F. Ryder, N. A.	.....do.....	Memorial Art Gallery, University of Rochester, N. Y.
30. Falling Snow, New York.	Everett L. Warner, A. N. A.	.....do.....	Carolina Art Association, Charleston, S. C.

"The Fall Round Up," by Carl Rungius, N. A. (No. 11 in the 1922 report), recorded as assigned to the Corcoran Gallery of Art, has been transferred to the Bruce Art Museum, Greenwich, Conn.; and "Repose of Evening," by Ben Foster (No. 12 in the 1922 report), recorded as assigned to the San Francisco Museum of Art, has been transferred to the University of Michigan, Ann Arbor, Mich.

It may be mentioned in this place that, as provided by the terms of the bequest, all works purchased by the Ranger fund are later subject to transfer to the National Gallery, as directed in the fol-

lowing extract from the last will and testament of Henry Ward Ranger:

All pictures so purchased are to be given by the council to art institutions in America, or to any library or other institutions in America maintaining a gallery open to the public, all such gifts to be upon the express condition that the National Gallery at Washington, administered by the Smithsonian Institute shall have the option and right, without cost, to take, reclaim, and own any picture for their collection, provided they exercise such option and right at any time during the five year period beginning ten years after the artist's death and ending fifteen years after his death, and, if such option and right is not exercised during such period, the picture shall remain and be the property of the institution to which it was first given.

NATIONAL GALLERY LIBRARY

Accessions to the gallery library Nos. 1-325 have been recorded from various sources as gifts, purchases, and exchanges, and include bound and unbound volumes and pamphlets.

PUBLICATIONS

Holmes, W. H. Catalogue of collections, I, National Gallery of Art. Government Printing Office, 1922. 8vo, pp. i-vi; 1-98, 25 plates and 1 ground plan.

This is the first number of the catalogue series of the gallery which is to be issued from time to time as conditions warrant. It follows in general the form of the catalogues of the art collections of the National Museum prepared by former Assistant Secretary Rathbun (Bull. 70, U. S. N. M., 1916), which was published, however, before the gallery became a separate department of the Institution. It contains an introduction by the director, giving a brief account of the development of the art interests of the Institution and an outline of the organization of the gallery. This is followed by a list of the art works acquired previous to November, 1921, with brief biographies of the artists. It is illustrated with a ground plan and full page halftone plates of 25 of the most noteworthy of paintings and sculptures in the gallery.

— Report on the National Gallery of Art for the year ending June 30, 1922. Appendix 2, Report of the Secretary of the Smithsonian Institution: Washington, Government Printing Office, 1922, pp. 42-54. Separate.

A two-page leaflet on the National Gallery has also been issued which, like the recent leaflets on the Smithsonian Institution previously issued, is to have wide distribution. It is intended to bring forcibly to the attention of the public the great need of a separate building to house the national art collections.

Respectfully submitted.

W. H. HOLMES,
Director, National Gallery of Art.

Dr. CHARLES D. WALCOTT,
Secretary, Smithsonian Institution.

APPENDIX 3

REPORT ON THE FREER GALLERY OF ART

SIR: I have the honor to submit the third annual report on the Freer Gallery of Art for the year ending June 30, 1923.

THE COLLECTION

Work completed during the year includes the examination, classification, and preliminary cataloguing of Chinese and Japanese stone sculptures and jades begun in 1922. New work undertaken includes the preliminary cataloguing and final storage of Chinese and Japanese bronzes, lacquers and wood sculptures, Near Eastern and Egyptian pottery, and miscellaneous objects of bone, ivory, metal, glass, etc., from various sources. Much additional work has been done on the preservation of oil paintings, and one Chinese *kakemono* has been remounted in panel form. The autumn, winter, and early spring were largely devoted to the installation of exhibits and to other preparations for the opening of the gallery to the public on May 2, involving the construction of cases according to designs previously made, the designing of pedestals, special stands, mounts, and easels and the execution of these under direct supervision of the curator and the superintendent, the choice, exhibition, and labeling of objects, the transfer of books to shelves provided for them in the east study room, and the preparation of a brief pamphlet setting forth the history of the Freer collection, together with necessary information regarding the purpose and use of the building and collection. This pamphlet was given to visitors during the opening week and has since been sold for 5 cents a copy, having reached a second printing of 3,000 copies. In June the making of identification photographs for the catalogue cards was begun.

BUILDING AND EQUIPMENT

Work accomplished during the year includes the completion of several undertakings mentioned in the second annual report, such as finishing gallery walls and floors, picture frames and screen boxes, as well as many new tasks completed or begun and the inevitable re-

pairs due to normal settling of the building and to ordinary wear and tear. For the exhibition galleries, the workshop has turned out 52 cases, and has 12 others "in work"; also 9 easels, 22 pedestals, 15 special stands, 40 block plinths, 5 large frames for screens, stone sculptures and tiles, 100 reeded frames for etchings, 3 molded composition bases for stone sculptures, and 5 sets of barricade stands have been made; while 6 walnut panels for the exhibition of scrolls and 19 benches were contracted for and built outside. On the ground floor, the east study room has been furnished with cork flooring, bookcases, and a desk, the latter made in the workshop. The offices, storage rooms, workrooms, and lavatories have received additional equipment, including desk lights with necessary floor outlets, metal shelving, cupboards, a set of portable shelves for photographic work, glass door panels, extra locks, electric fans, etc. The fan room floor has been painted, and in the attic blue size has been applied to the skylights and cotton curtains have been hung above the ceiling lights for the purpose of modifying both light and heat. In the cellar two columns have been constructed under the partition wall between two rooms in the northwest corner of the building. To the equipment of the court fresh soil and a few trees have been added, as well as three peafowl from the National Zoological Park and a supply of goldfish from the Fish Commission. Indebtedness to these two organizations is gratefully acknowledged.

OPENING AND ATTENDANCE

The formal opening of the gallery took place during the week of May 2 to 8, inclusive. It was preceded by a "press view" on the morning of May 1, and a private view for the Establishment and Regents of the Smithsonian Institution on the afternoon of the same day. For the opening week 3,300 invitations were issued.

Total attendance for May, 19,274.

Largest attendance on Sundays, averaging 1,022.

Smallest attendance on Mondays, averaging 406.

Total attendance for June, 13,474.

Largest attendance during the week of the Shriners' convention, 1,158 and 1,202 on June 6 and 7, respectively, with an average attendance of 548 on other days. During the rest of the month the largest attendance was on Sundays, with an average of 490, and the smallest on Mondays, with an average of 211.

Attendance in the study rooms for May and June, 186 persons, of whom 4 brought in objects for examination and 11 received permission to copy.

Total attendance for May and June, 32,648.

After June 11 a new regulation went into effect, namely, that the building should be open from 9 until 4.30 every day of the week

except Monday, when it should be closed all day. This serves a double purpose in that it not only makes the exhibitions available to many people who are unable to come on week days, but also gives opportunities for necessary work which can not be so well undertaken when the building is open to visitors.

FIELD WORK

IN EUROPE

The months of July and August were spent by Miss Guest in Europe and were devoted to a study of various collections of Oriental art, following her attendance as delegate from this gallery to the meetings of the Société Asiatique de Paris, held in Paris from July 10 to 13, in celebration of the centenary of Champollion. Among the most important groups of objects studied were:

The collections of the Mission Pelliot, exhibited in the Musée Guimet and the Musée du Louvre.

The partly dismantled but important loan exhibition of Oriental pottery and stone sculpture at the Musée Cernuschi.

The collections of M. Raymond Koechlin and M. Calmann.

The Central Asian paintings collected by Sir Aurel Stein and deposited in the British Museum.

The objects from Turfan collected by Professor Von le Coq and now stored in the Völkerkunde Museum, and those from Samarra collected by Dr. Friedrich Sarre and now exhibited in the Kaiser Friedrich Museum, Berlin.

Miss Guest spent several days also in the pottery works of Staffordshire, England, where she was given every facility for examining materials and processes of manufacture.

Miss Guest's more detailed account of her field activities accompanies this report as Appendix A (not printed).

IN CHINA

On February 12, Mr. Bishop left here for China, in charge of an archeological expedition sent out under the joint auspices of the Freer Gallery of Art and the Museum of Fine Arts, Boston. Working in accordance with instructions, but of necessity largely at his own discretion, Mr. Bishop's chief concern so far has been with matters of organization, which he has managed and now settled more successfully than might reasonably have been expected. He has also visited several sites of great archeological interest and made observations of importance to the future work of the expedition.

Mr. Bishop's detailed account of his field activities accompanies this report as Appendix B (not printed).

PERSONNEL

Katharine Nash Rhoades was appointed associate, her appointment to take effect July 1.

Kwang-zung Tung was appointed field assistant, his appointment to take effect July 1.

Archibald Gibson Wenley was appointed field assistant on June 1.

Ruth L. Walker, stenographer, handed in her resignation, to take effect July 1.

Respectfully submitted.

J. E. LODGE, *Curator.*

Dr. CHARLES D. WALCOTT,

Secretary, Smithsonian Institution.

APPENDIX 4

REPORT ON THE BUREAU OF AMERICAN ETHNOLOGY

SIR: In response to your request I have the honor to submit the following report on the field researches, office work, and other operations of the Bureau of American Ethnology during the fiscal year ended June 30, 1923, conducted in accordance with the act of Congress approved June 12, 1923. The act referred to contains the following item:

American ethnology: For continuing ethnological researches among the American Indians and the natives of Hawaii, including the excavation and preservation of archeologic remains, under the direction of the Smithsonian Institution, including the necessary employees and the purchase of necessary books and periodicals, \$44,000.

The chief has endeavored to expend the sum of money allotted in as conservative and economical a manner as possible, although confronted with many difficulties, among which is the increased cost of field work. Since the bureau was first organized expenses for its maintenance have greatly increased, and have doubled within the last 10 years. Several other tendencies of the times have limited the production of results. There has been a great awakening of interest in the treatment of certain Indian tribes by Government officials which has led to a corresponding increase in requests for our publications. Never before was there a greater demand for the published reports and bulletins of the bureau. The epoch-making discoveries in the Valley of the Tombs in Egypt have very greatly increased interest in the Science of Man and the desire for more accurate knowledge of prehistoric man in American is very keen. Newspapers, magazines, and other periodicals have done much to increase this interest and, as may be said with regret, many fake discoveries have been foisted on the public. Never before have accurate accounts of Indian life like those published by the Bureau of American Ethnology been more in demand than at the present time.

Several wealthy institutions have been led to give more money to American anthropology. Plans for archeological work in Yucatan and Central America costing many thousands of dollars a year are mentioned in some quarters, and many thousands are annually expended by another institution on pueblo archeology. For lack of adequate funds, the bureau is unable to carry on extensive work of this magnitude and it remains for the bureau to continue its work

along the lines already successfully followed—by researches and publication of the results of less ambitious plans. It can not be expected that the quantity of field work with this handicap can be as great as it was when the field was almost untilled, but the chief is striving to keep the quality up to the past. For years to come as the culture of our aborigines fades into the past there will be plenty of work to do in gathering survivals and publishing reports to meet increased demand for authoritative literature on our aborigines. As the work of the bureau calls for increased popularization, in the judgment of the chief, the bureau should enlarge the number of popular articles which it publishes from time to time without decreasing strictly technical discoveries. The pages of our reports are full of the records of discoveries which are little known and at present interest only a few persons because of that fact. This should be obviated by putting into published form, suitable for the layman or for students in schools and colleges, the vast stores of knowledge which have been made by the staff of the bureau and its collaborators. The great success of the Handbook of American Indians clearly indicates the desire of the people for popular information on our aborigines and the bureau with an enlarged appropriation would be able to continue work of this nature.

In compliance with the act of Congress above mentioned the Bureau of American Ethnology has continued its field and office researches on the American Indians including the ethnology of the Hawaiian Islands, and the inhabitants of Porto Rico and the Virgin Islands. Later in this report is a list of the annual publications. The high cost of printing has somewhat reduced the quantity but the quality has been maintained.

The rapid modification in aboriginal culture perceptible year by year in Indian manners, customs, and languages has led the chief of the bureau to encourage archeological and historical study of the Indians. Extensive researches have been carried on in Colorado, in the Harpeth Valley, Tenn., in the Ozarks, Mo., and on the Atlantic seaboard. In addition to archeological research considerable work has been done on documentary history, especially of the Creeks, Choctaws, and other Muskogean tribes.

Although the bureau has hitherto published many memoirs on the Indians of the northwest coast, there still remains much ethnological work awaiting investigation in this territory. A very promising beginning was made in the study of the totem poles of this region by Dr. T. T. Waterman, a temporary assistant on the staff of the bureau who made a special trip to Alaska for that purpose. He not only collected considerable new material on totem poles but also on legends connected with them.

The intention of the chief is to continue the work thus inaugurated in Alaska, and to repair one of the old Indian villages for educational purposes. The former houses of the Alaska natives are now rapidly going to destruction; Kasaan, one of the largest, was deserted and has been made a national monument but is suffering for want of care. It is proposed to begin cleaning up this village, repair it, in order to minimize the dangers from fire and vandals, and put it in a condition to afford the greatest educational value to future students and tourists.

The first duty of the chief being administrative in nature much of his time is taken up by details of office work, in which, unless assisted by the members of the bureau, he would be greatly handicapped. The work of answering letters has greatly increased in the last five years, and the demands on the time of those engaged in it have been greatly multiplied. This has affected all members of the staff, but it is very satisfactory to record that the letters in reply to inquiries are treated with the greatest respect and are looked upon as authoritative by the recipients.

When in Washington the chief has attended all meetings of the advisory committee on publications and one or two other committees to which he has been appointed. He has likewise accepted the welcome duty of keeping in touch with all the archeological expeditions from different institutions working on ruins in the area of the United States in order that he might intelligently advise action to the secretary on the requests for permits to carry on archeological excavations, which each year are increasing in numbers.

The chief has made strenuous efforts to continue his studies of previous summers on the Mesa Verde National Park in cooperation with the National Park Service of the Department of the Interior. In July, August, and a part of September he was absent from Washington and completed the excavation of Pipe Shrine House, a building in the Mummy Lake group of mounds. An account of the initiation of this work appeared in the report for last year. This exceptional ruin was completely repaired and is now open for inspection of visitors.

The excavation and repair of a circular tower situated 300 feet from Far View House also engaged his attention from the middle of July until the close of the season. The mound of stones covering this ruin was known as far back as 1915, but its hidden building was not revealed until the close of June of the summer of 1922, when it was found to be a tower with three subterranean rooms, called kivas, which were evidently used for ceremonial purposes. Around these rooms was formerly a crowded cemetery, of ancient date, which led him to regard the whole area as a necropolis. The number

of interments was too large for the number of dwellings. The three kivas belong to the highest type of these structures characteristic of the Mesa Verde. In one of them there was a well-made wall of secondary construction showing a secondary occupation and ruder masonry. This kiva showed signs of having been abandoned and later reoccupied, but how many years elapsed between the two occupations was not evident from data available.

The excavation of this Mesa Verde tower led to new ideas of the structure and use of these remains, hundreds of which are found scattered in the canyons and on the mesas of the northern tributaries of the upper San Juan River. This tower is a fair example of the type of these buildings. It was probably an outlook for observations of the sun and ceremonies connected with the sky god.

The first type of tower recognized in the Mesa Verde is a simple lookout situated naturally on the summit of a hill or high elevation, but unaccompanied by any other building; the second type has basal rooms which apparently are used for storage of food or possibly for habitation. Far View Tower is classified in a third type, in which we have a tower rising from basal subterranean kivas, granaries, and dwellings. The purpose of this type of tower is the same as Pipe Shrine House.

During the greater part of August the tops of the walls of Far View House were covered with cement to protect them from the elements, and it is believed the protected walls will remain upright for several years without further repair. The permanent protection of these open ruins is always difficult and costly, but necessary. There still remain many unsolved problems on the Mesa Verde awaiting attention, but with small appropriations new ruins can not be opened and those already opened can not be repaired.

Some distance north of Far View Tower is the depression long ago christened Mummy Lake. Its true nature is unknown, though it may have been a reservoir; but no mummies have ever been found in its vicinity. In the thick cedars about it, situated on the right hand of the road, there are several small mounds indicating ruins, generally habitations, surrounding kivas. In one of these there are walls made of large stones set on edge, standing above ground. These stones project 4 feet above the surface, and their size has led to the ruin being called Megalithic House. Excavation work on this ruin was begun but not completed before the appropriation was exhausted.

About every other night during the five months the chief worked on the Mesa Verde he gave camp-fire talks to visitors and spent considerable time daily in explaining the signification of the excavations while they were in progress.

In June, 1923, the chief made a trip to Deming, southern New Mexico, and visited different localities, Fort Bayard, Central, Silver City, and Pinos Altos, where pictured food bowls have been found. He purchased a beautiful collection of pottery from the Mimbres Valley, which supplements that already installed in the Museum.

In 1914 the chief first pointed out that the Mimbres Valley, in which this pottery is found, was inhabited in prehistoric times by a people who excelled all other pueblos in painting realistic figures on pottery. The scientific value of these pictures is very great from the fact that the prehistoric dwellers in the Mimbres Valley in this way left a reliable and permanent record of certain occupations (hunting, fishing, gambling), as well as wonderful representations of mythological animals of all varieties. If we could truthfully interpret these figures, our knowledge of the prehistoric mythology of a people of whose history, language, and relationship we know nothing from documentary sources would be greatly increased.

Not far from the close of the fiscal year, President Harding issued a proclamation declaring three groups of towers in southwestern Colorado and southeastern Utah to be a national monument. This announcement was particularly gratifying to the chief, not only because it preserved for future generations good examples of unique types of ancient buildings in our southwest but also because the idea of the reservation of Hovenweep National Monument originated in the Bureau of American Ethnology. The three groups composing this monument lie within a few miles of each other and are locally called Ruin Canyon group, Holly Canyon group, and the Tejon Mesa group.

During the fiscal year Dr. John R. Swanton, ethnologist, has completed the following manuscripts: "Social Organization and Social Usages of the Indians of the Creek Confederacy"; "Religious Beliefs and Medical Practices of the Creek Indians"; and "A Grammatical Sketch of the Alabama Language."

Doctor Swanton also completed a card catalogue, arranged under stems, of all of the linguistic material contained in the *Arte de la Lengua Timuquana*, by Francisco Pareja, and an English-Indian index for the same; and initiated a report on the stories of the southeastern Indians. By July 1 he had completed translations of stories in the Koasati language and made a beginning on those in Alabama. Material was added to his collection of references bearing on the economic basis of American Indian life, and some map work was done in connection with this phase of Indian life.

The 1st of July, 1923, found Dr. Truman Michelson, ethnologist, at work among the Fox Indians of Iowa. He collected sufficient material for a manuscript entitled "The traditional origin of the

Fox Society, known as 'They who go about singing' (singing-around rite)." This material will be published in the Fortieth Annual Report of the bureau. A good beginning was also made on the ceremonial "runners" and attendants. Tribal dissensions at Tama cut short Doctor Michelson's stay among the Fox Indians and he made a reconnaissance among the Potawatomi of Wisconsin, the Chippewa at Reserve in the same State, the Ottawa of Michigan, the Delaware-Munsee of Lower Canada, and the Montagnais of Lake St. John, returning to Washington near the 1st of October. He definitely determined that there are several different Delaware dialects spoken in Canada and the United States, and that some of these dialects are not clearly related; so that the word Delaware is merely a "catch all" term.

After returning to Washington Doctor Michelson devoted his time to elaborating the paper above mentioned on "The traditional origin of the Fox Society, known as 'The Singing-around rite'," completing it for publication.

About the middle of May Doctor Michelson left for the field to make a reconnaissance of the Algonquin tribes of eastern United States and Canada, including the Labrador Peninsula. His observations lead him to conclude that the aboriginal culture of the Penobscots at Old Town, Me., is disintegrating. None of the young people speak the language, and with the constant intermarrying with whites it will be but a short time when ethnology and folklore, which are both well remembered, will be a thing of the past. The Malecites living at the "village," about 12 miles from Fredericton, New Brunswick, cling tenaciously to the language, which is spoken universally, though practically everyone also has a good command of English. Their ethnology, on the other hand, is fast disappearing. During his short visit with the Penobscots and Malecites, Doctor Michelson determined a number of peculiar morphological traits of the language as compared with central Algonquian. He finds the phonetics of both languages extremely difficult, and on the whole it may be said that neither language is archaic in type. On June 13 Doctor Michelson arrived in Sydney Cape Breton, Nova Scotia, en route to Labrador.

The beginning of the fiscal year found Mr. John P. Harrington, ethnologist, engaged in the preparation for publication of his recent field notes on the Picurís and Taos tribes of New Mexico and the Mission Indians of California. All the notes on the Taos Indians collected by the late Mrs. M. C. Stevenson were copied and arranged for publication.

Mr. Harrington also prepared for publication a paper entitled "Picurís Children's Stories with Texts and Songs." This manu-

script embraces Picurís stories in native text such as are told to the Indian children on winter evenings in their little isolated village in northern New Mexico. The stories have high literary quality, and many of them hold the attention of child or adult throughout. The volume is thought to be practical for school use. The 12 songs accompanying the stories are beautifully rendered by Mr. Rosendo Vargas, and are transcribed into musical notation by Miss H. H. Roberts.

Mr. Harrington also prepared an article on "How the World Grew," which is an account of origins corresponding to the book of Genesis of the Bible obtained from the Mission Indians of California.

Mr. Cipriano Alvarado, a Quiché Indian of the highlands of Guatemala, was brought to this country for the purpose of linguistic study by Mr. William Gates, who kindly allowed Mr. Harrington to obtain from him a large amount of text material in this language. The Quiché is the direct descendant of the tongue of the ancient temple builders of the Central American jungles. In working with Mr. Alvarado with the kymograph, Mr. Harrington discovered that the Quiché and other Mayan dialects possess tones exactly like those of Chinese, and that these tones, as in the latter language, are often the sole means of distinguishing words that are otherwise phonetically identical. Work was also done with Mr. Alvarado and Mr. Gates on the pallophotophone, a machine recently invented by Professor Hoxie, of the General Electric Co. The pallophotophone proved of the greatest value for the study of tones in Indian and other languages, and its reproduction of the voice is true for all the sounds, even including s, h, and those of like timbre which are imperfectly rendered on the phonograph.

On May 3 Mr. Harrington proceeded to Santa Barbara, Calif., for the purpose of continuing his researches on the Indians of that State. He succeeded in finding good informants for Indian songs as well as stories and place names and obtained a large quantity of manuscript material. This material consists of myths, place names, historical notes, accounts of early life and customs, genealogies, and Indian songs.

The Bureau of American Ethnology is doing cooperative work with the Museum of the American Indian, Heye Foundation, of New York City, which obtained permission from the Hotel Ambassador Corporation to excavate the famous Burton Mound on the beach at Santa Barbara. This mound has always been known as the site of the principal rancheria of the Santa Barbara Indians, but former owners of the property refused permission to excavate it, and when the Potter Hotel was erected in 1901 hope of archaeological investigation seemed forever lost. The site was unexpectedly made again

available for study on account of the burning of the hotel a few years ago.

The excavations began early in May and the Indian cemetery was located on the slope of the mound toward the beach. The graves that were opened were crowded with human bodies, trinkets, and a great variety of utensils. Among the specimens are a fragment of a soapstone canoe, soapstone pipes, fishhooks of abalone and bone, sinker stones, arrowheads of great variety, spear heads, about 40 mortars, pestles, including some very long ones, beads of many kinds, pendants, daggers, bowls and kettles of soapstone, native paint, etc.

Mr. Harrington has prepared for publication during the fiscal year approximately 1,900 pages of manuscript.

Mr. J. N. B. Hewitt, ethnologist, completed during the fiscal year the second part of his Iroquoian Cosmology, the first part having appeared in the Twenty-first Annual Report of the bureau.

During the year Mr. Hewitt spent some time editing a manuscript entitled "Report on the Indian Tribes of the Upper Missouri," by Mr. Edwin Thompson Denig, to the Hon. Isaac Stevens, Governor of Washington Territory in 1854 (?), which has been submitted for publication.

Mr. Hewitt devoted much time and research in the preparation of data for official replies to correspondents of the bureau. These inquiries in their scope touch almost the entire range of human interest, very often seeking information quite outside of the specific field of research belonging to this bureau. About 100 such replies were prepared, although some of them required more than a day's work in preparation.

Mr. Hewitt also acted as the representative of the Smithsonian Institution on the United States Board of Geographic Names.

On May 18, 1923, Mr. Hewitt left Washington on field duty. His destination was the Grand River Grant to the Six Nations of Iroquois dwelling near Brantford, Ontario, Canada. At this place Mr. Hewitt made an intensive study and revision and fuller interpretation of his voluminous texts—texts which he had recorded so fortunately in previous visits to this place. These texts embody the traditions of the founding of the League or Confederation of the Five Tribes of the Iroquois in the closing decades of the sixteenth century. They contain also the principles and laws upon which it was established, as well as the complete rituals and chants of the Council of Condolence and Installation of the Federal Government, was established, as well as the complete rituals and chants of the kindreds composing the tribal members of the league.

He was also fortunate in recovering enough data relating to the Federal and tribal chieftainesses to enable him to affirm the former existence of a set of official names for every one of these women

magistrates. He also recorded much valuable information relating to the several institutions of the league.

On June 24, Mr. Hewitt made a short visit to the Onondaga Reservation, lying about 8 miles south of Syracuse, N. Y. He devoted his time on this reservation to a comparison of the limited knowledge possessed by the only two men who had any definite information of the various institutions and laws and installation rituals of the Iroquois Confederation, with the records which he possesses. The object was to ascertain, if still possible, how much of his Canadian material, if any, could be said to be recent, or whether the differences in the content were due merely to the breakdown of the traditions of the New York Onondaga. He convinced himself that the latter was the sole cause.

Mr. Francis La Flesche, ethnologist, was engaged most of the time during the fiscal year in assembling his notes for the third volume of his work on The Osage Tribe. In this volume are recorded two rituals of the Osage tribal rites. One is entitled *Wa-xo'-be A-wa-tho'*, Singing of the *Wa-xo'-be* Songs, and the other, *Ça Tha-çe Ga-xe*, Weaving of the Rush.

SPECIAL RESEARCHES

In her studies of Indian music during the fiscal year Miss Frances Densmore has included the songs of three tribes living in Arizona, near the Mexican border. These tribes are the Yuma, Mohave, and Papago. One of the manuscripts submitted this year deals with the cremation ceremony of the Yuma, witnessed by Miss Densmore in 1922. The ceremonial songs of this rite were recorded and information given by the oldest man, who has the hereditary right to sing these songs. It is the custom of the Yuma Indians to hold a memorial ceremony within a year after a death, at which an image of the deceased is burned. After this ceremony the name of the dead is never spoken. A full description of this ceremony was submitted, together with transcriptions of its songs.

The treatment of the sick by these tribes was also studied and healing songs of each tribe were submitted. Among these were the songs of a Yuma medicine man, who claims the power to cure persons suffering from wounds in the chest, accompanied by hemorrhage. This shaman said that he did this by the aid of four insects and birds, one of which has power over the fluids of the body. His songs are cheerful and soothing in character, and it is interesting to note that he forbade the people to weep during his treatment, requiring that they "appear cheerful and act in a natural manner."

Four manuscripts were submitted by Miss Densmore during the year, bearing the following titles: "Papago medicine and dancing

songs," "Dream and war songs of the Papago Indians," "Cremation and memorial ceremonies of the Yuma Indians, with related songs," and "Lightning and medicine songs of the Yuma and Mohave Indians." This material comprised 93 pages of manuscript and 84 transcriptions of songs, together with the original phonographic records and tabulated and descriptive analyses of the songs. The two most interesting musical discoveries made in this work are the presence in these tribes of songs which may be termed "pure melody without tonality," and the independent and elaborated rhythm of the accompanying instrument, either a gourd rattle or a basket drum. In many instances the accompanying instrument is transcribed separately from the melody in order to show its peculiarities.

During the summer of 1922 Miss Densmore visited the Chippewa reservations at Lac Court Oreilles, Wis., and Leech Lake and Mille Lac, Minn., collecting additional specimens of plants used in treating the sick, and other data.

In the spring of 1923 Mr. W. E. Myer, special archeologist, spent several months investigating archeological remains in central Tennessee. He visited the ancient mound group of the Banks Link farm on Duck River, in Humphreys County, Tenn., where was found the celebrated cache of fine, long flint blades and other flint objects now the pride of the collection of the Missouri Historical Society. He made a map of this group and obtained additional information in regard to these masterpieces of the ancient flint-chipper's art.

Through the active aid of several citizens of Lincoln County he was enabled to visit and study an important and hitherto undescribed mound group on Elk River, at the junction of Lincoln, Moore, and Franklin Counties. He also obtained the definite location of over 75 unrecorded sites on which ancient man had lived in Lincoln County.

He explored a small burial mound and other vestiges of an ancient Indian village on the lands of Mr. L. W. Denny, Goodlettsville, Davidson County, Tenn., where he found 20 skeletons. There was evidence that two different tribes had occupied this site at separate times in the past, and the mound yielded a number of fine artifacts which throw light on the life of the people.

Mr. Myer spent two months exploring the remains of a great prehistoric fortified Indian town in Cheatham County, Tenn., known as the Great Mound Group on account of its great central mound. With the assistance of Mr. Wilbur Nelson, State geologist of Tennessee, an excellent topographical map was made, and through the repeated efforts of Lieut. Norman McEwen, of the 136th Air Squadron, Tennessee National Guard, some good airplane photographs of the mound on the Harpeth River, near Kingston Springs, were secured.

These remains cover approximately 500 acres in two bends of the river. In one bend he found a bold projecting hill which had been artificially shaped from bottom to top. Three wide terraces had been formed along the side of this hill. The original rounded summit had been leveled until a great plaza or public square, about 1,000 feet in length and 500 feet in breadth, had been formed. Upon the sides of this level plaza one very large mound and two smaller ones had been erected. This section of the ancient town was protected on the water side by the perpendicular cliffs of the Harpeth River. On the land side it was defended by an earthen embankment or breastworks surmounted by a wooden wall, from which at intervals semicircular wooden towers projected. These earthen breastworks, which had formerly supported this wooden wall, were still to be found in the undisturbed woodlands, where they yet extend about $1\frac{1}{4}$ miles, and there is evidence that they originally ran much farther. Wooden palisades, consisting of small tree trunks, had been driven into the ground side by side and wedged together and the soil thrown against them until they were by this means firmly embedded in these earthen embankments or breastworks. These palisades, bound closely together and strongly braced, formed a wooden wall which had been plastered on the outside in order to make scaling by an enemy difficult. Earthen bastions projecting beyond this line of wall at intervals of about 150 yards were still to be found. These had formerly supported the semicircular wooden towers. The enemy advancing to attack was therefore subjected to fire from the defenders through portholes along the main wall and also to a flanking fire from the warriors in the towers on these bastions. Faint traces of some of the timbers of these palisades and wooden towers were found in the soil of these embankments.

While the great central mount and terraced hill formed the most striking feature of this ancient town, there were in the inclosure four other eminences whose summits had likewise been leveled into plazas. All these plazas yielded traces of earth lodges and other evidences of former buildings. The earth lodges of the common people were situated on the edges of the terraces. The larger mounds had probably supported important public buildings and the lodges of leading personages. This grouping of important buildings around five separate plazas and in different parts of the town very probably indicates that the population was made up of what had once been four or five separate autonomous groups of kindred peoples. Here in their later home each group had gathered around their own public square in their own section of the town and thus preserved at least some of their old ceremonials and held together in some fashion their old organization.

It is impossible to determine even approximately the number of inhabitants, but the large number of the buildings and the long extent of the walls indicate a population of several thousand. All the buildings whose traces were uncovered appear to have been burned. Below the fallen-in wall of an important building the charred remains of the woven reed tapestry which had formerly hung upon the wall were secured for the National Museum.

It is not as yet possible to determine the age of these remains. Beyond all question this town had been destroyed long before the coming of the whites. No object of white man's manufacture was found on this site.

Mr. Gerard Fowke carried on archeological investigations in the Stratman Cave in Maries County, Mo. This cave, which is situated a little more than 2 miles south of Gascondy, the point at which the Rock Island Railroad crosses Gasconade River, has an opening on the side of a hill about 150 feet high. The approach to the cave on the river side is very steep, but from the top of the hill it is less difficult. Mr. Fowke opened a trench on the outside slope of the talus at a point 30 feet from the entrance of the cave and 16 feet below the floor level. He found most of the evidences of human occupation in superficial black earth, scattered throughout which from bottom to top were fragments of pottery, parts of vessels of varying capacity and thickness; chert knives or spearheads, none highly finished; hundreds of thousands of mussel shells more or less decayed; and other objects so abundantly found on the numerous camp sites and village sites along the Gasconade River. The artifacts were few in number and scattered throughout the mass, nowhere more than a few pieces in a cubic foot of earth. This denotes temporary occupation, at irregular intervals, over a long period of time. Yet the cave was not altogether merely a resort for temporary hunters or war parties. In addition to the pottery, which shows at least occasional sojourning in the cave, there were fragmentary bones, too fragile to preserve, of a child 2 or 3 years old, of another somewhat older, and a small adult, possibly a woman. These bones were found in different places but near the surface; there were no other indications of burials. The only specimens found worthy of note were a small hammer made of a chert twin-concretion and bearing evidence of long service; a pebble, used for sharpening small bone implements and for smoothing leather or rawhide strings; and a double concave discoidal with V-shaped margin.

While the results of the work at Stratman Cave contributed little to the antiquity of man in Missouri, Mr. Fowke's studies, which are accompanied by a small collection, are valuable in a comparative

way. The Ozark region in Missouri is yielding many surprises to the archeologist and it is believed that there still remains much field work to be done here and in the neighborhood before the character and antiquity of the Indians of that region are definitely determined.

With a small appropriation Mr. John L. Baer carried on instructive field studies on the banner stones in the Susquehanna River region, and was able to make a good series reaching from the imperfect form into the more symmetrical objects. He also investigated the pictographs found near Delta, Pa.

EDITORIAL WORK AND PUBLICATIONS

The editing of the publications of the bureau was continued through the year by Mr. Stanley Searles, editor, assisted by Mrs. Frances S. Nichols, editorial assistant. The status of the publications is presented in the following summary:

PUBLICATIONS ISSUED

- Thirty-fourth Annual Report. Accompanying paper: A Prehistoric Island Culture Area of America (Fewkes). 281 pp., 120 pls., 69 figs.
 Thirty-seventh Annual Report. Accompanying paper: The Winnebago Tribe (Radin). 560 pp., 58 pls., 38 figs.
 Bulletin 76. Archeological Investigations (Fowke). 204 pp., 45 pls., 37 figs.
 Bulletin 77. Villages of the Algonquian, Siouan, and Caddoan Tribes west of the Mississippi (Bushnell). 211 pp., 55 pls., 12 figs.

PUBLICATIONS IN PRESS OR IN PREPARATION

- Thirty-eighth Annual Report. Accompanying paper: An Introductory Study of the Arts, Crafts, and Customs of the Guiana Indians (Roth).
 Thirty-ninth Annual Report. Accompanying paper: The Osage Tribe: The Rite of Vigil (La Flesche).
 Fortieth Annual Report. Accompanying papers: The Mythical Origin of the White Buffalo Dance of the Fox Indians; The Autobiography of a Fox Indian Woman; Notes on Fox Mortuary Customs and Beliefs; Notes on the Fox Society known as "Those Who Worship the Little Spotted Buffalo"; The Traditional Origin of the Fox Society known as "The Singing-Around Rite" (Michelson).
 Forty-first Annual Report. Accompanying paper: Social Organization and Social Usages of the Indians of the Creek Confederacy (Swanton).
 Bulletin 78. Handbook of the Indians of California (Kroeber).
 Bulletin 79. Blood Revenge, War, and Victory Feasts among the Jibaro Indians of Eastern Ecuador (Karsten).
 Bulletin 80. Mandan and Hidatsa Music (Densmore).
 Bulletin 81. Excavations in the Chama Valley, New Mexico (Jeancon).
 Bulletin 82. Fewkes and Gordon Groups of Mounds in Middle Tennessee (Myer).

DISTRIBUTION OF PUBLICATIONS

The distribution of publications has been continued under the immediate charge of Miss Helen Munroe, assisted by Miss Emma B. Powers. Publications were distributed as follows:

Annual reports and separates_____	5,363
Bulletins and separates_____	11,787
Contributions to North American Ethnology_____	10
Introductions _____	3
Miscellaneous publications_____	531
	<hr/> 17,694

As compared with the fiscal year ending June 30, 1922, there was an increase of 3,479 publications distributed.

ILLUSTRATIONS

Mr. DeLancey Gill, illustrator, with the assistance of Mr. Albert E. Sweeney, continued the preparation of the illustrations of the bureau. A summary of this work follows:

Drawings for publications_____	32
Photographs retouched for engraving_____	78
Illustration copy made ready for engraving_____	319
Illustrative proof edited_____	302
Editions of colored plates examined at Government Printing Office___	160,000
Negatives prepared_____	232
Films developed from field exposures_____	240
Prints for distribution and office use_____	1,117

In November of last year Mr. Gill began to reclassify the large collection of ethnologic and archeologic negatives with a view of preparing a comprehensive catalogue of the linguistic families and tribes with such historic data as is available. He has made good progress in this work. About 5,000 negatives have already been catalogued.

LIBRARY

The reference library continued under the immediate care of Miss Ella Leary, librarian, assisted by Mr. Roderick McPherson and later by Mr. Thomas Blackwell.

During the year 500 books were accessioned. Of these 70 were acquired by purchase, 130 by gift and exchange, and 300 by binding of periodicals. The current periodicals annually received number about 925, of which 35 are by subscription, the remainder being obtained through exchange. The bureau has also received 200 pamphlets. The aggregate number of volumes in the library at the close of the year was 25,061; of pamphlets about 15,100. Satisfactory progress was made toward the completion of the new subject catalogue from the old imperfect author's catalogue.

The most pressing need which confronts the library is shelving for the ever increasing accumulations of books. Extensive shiftings and readjustments have been necessary during the year in order to make space available where it is most needed, but the library is totally lacking in facilities to allow for its expansion.

COLLECTIONS

The following collections, acquired by members of the bureau or by those detailed in connection with its researches, have been transferred to the United States National Museum:

69367. Archeological objects from Alaska collected by Dr. T. T. Waterman in the spring of 1922. (5 specimens.)
69530. Stone collar from Mayaguez, Porto Rico.
69660. Two incense burners found in a cave in southern Yucatan and presented to the bureau by Maj. E. H. Ropes, United States Army.
69881. Archeological specimens collected along the Susquehanna River (Maryland and Pennsylvania) in October, 1922, by John L. Baer. (174 specimens.)
69885. Two stone pestles from the Isle of Pines.

MISCELLANEOUS

Clerical.—The correspondence and other clerical work of the office has been conducted by Miss May S. Clark, clerk to the chief. Mr. Anthony W. Wilding served as messenger and typist to the chief.

Mr. Roderick McPherson, messenger in the library, resigned March 31, 1923, and Mr. Thomas Blackwell, minor clerk, was appointed May 1 to fill the vacancy.

Respectfully submitted.

J. WALTER FEWKES,

Chief, Bureau of American Ethnology.

Dr. CHARLES D. WALCOTT,

Secretary, Smithsonian Institution.

APPENDIX 5

REPORT ON THE INTERNATIONAL EXCHANGES

SIR: I have the honor to submit the following report on the operations of the International Exchange Service during the fiscal year ending June 30, 1923:

The work of the service having returned to a normal basis, an estimate of \$45,000 was submitted for carrying on the exchanges during the year, which is \$5,000 less than that appropriated for the fiscal year 1922. This appropriation was made by Congress and in addition \$200 was allowed for printing and binding. The repayments from departmental and other establishments amounted to \$5,263.66, making the total resources available during the year, \$50,463.66.

The total number of packages handled during the past 12 months was 377,826, a decrease from the number for the preceding year of 5,331. The total weight of these packages was 492,816 pounds, a decrease of 99,784. This large decrease in the weight was due to the fact that many of the packages sent abroad contained small publications.

The number and weight of the packages of different classes are indicated in the following table:

	Packages		Weight	
	Sent	Received	Sent	Received
			<i>Pounds</i>	<i>Pounds</i>
United States parliamentary documents sent abroad.....	141, 884		63, 325	
Publications received in return for parliamentary documents...		2, 557		12, 511
United States departmental documents sent abroad.....	120, 093		152, 169	
Publications received in return for departmental documents...		5, 852		18, 117
Miscellaneous scientific and literary publications sent abroad...	77, 461		154, 437	
Miscellaneous scientific and literary publications received from abroad for distribution in the United States.....		29, 979		92, 257
Total.....	339, 438	38, 388	369, 931	122, 885
Grand total.....	377, 826		492, 816	

Although it is true that the United States Government sends abroad more publications than it receives in exchange, the disparity is not so great as appears in the table, for many foreign publications are forwarded by mail to the addresses in this country without passing through the exchanges.

It was stated in the last report that the Government of Rumania had been approached with a view to the reopening of exchange relations with that country, and further that the Institution had arranged directly with the Institutul Meteorologic Central, at Bukharest, to take charge of the forwarding and distributing of exchange consignments. During the past year a communication has been received through the Department of State from the Government of Rumania to the effect that the above-mentioned institute had been designated as the official Rumanian Exchange Bureau. A note was received from Rumania, through the Belgian Government, stating that under date of June 5, 1923, the Rumanian Government had declared its adherence to the Brussels Conventions of 1886, providing for the exchange of official documents and scientific and literary publications and the immediate exchange of the official journal. For a number of years the exchange of official documents has been conducted with Rumania, although that country has only recently given its formal adherence to the conventions.

The conditions in Russia and Turkey have not yet improved sufficiently to warrant the Institution in taking steps to establish official exchange bureaus in those countries. The Institution has, however, arranged with the American Friends Service Committee to forward to Russia the large accumulations of scientific and literary publications for correspondents in that country. Two consignments, comprising a total of 70 boxes, have thus far been forwarded to Russia in this way. The Academy of Sciences in Petrograd is acting as the distributing agency.

There were shipped abroad during the year 2,223 boxes, being a decrease of 995 from the number for the preceding 12 months. This decrease in the number of boxes forwarded abroad, in comparison with the number shipped during the previous year, is due partly to the smaller size of many of the publications, to which reference has already been made, and partly to the fact that the number of boxes sent abroad last year was the largest in the history of the service, the usual number being about 2,400 annually. Moreover, packages for certain countries were sent direct to their destination by mail, owing to the fact that a sufficient number had not accumulated to make box shipments when the regular monthly consignments would have been forwarded. About 40,000 packages were forwarded in this manner during the year.

Of the total number of boxes sent abroad 214 contained full sets of United States official documents for foreign depositories and 2,009 included departmental and other publications for the depositories of partial sets and for miscellaneous correspondents.

The number of boxes sent to each country is given in the following table:

Consignments of exchanges for foreign countries

Country	Number of boxes	Country	Number of boxes
Argentina.....	48	Latvia.....	2
Austria.....	59	Lithuania.....	7
Belgium.....	69	Mexico.....	4
Brazil.....	39	Netherlands.....	68
British Colonies.....	4	New South Wales.....	35
Canada.....	16	New Zealand.....	19
Chile.....	23	Nicaragua.....	2
China.....	79	Norway.....	33
Colombia.....	16	Paraguay.....	2
Costa Rica.....	10	Peru.....	12
Cuba.....	4	Poland.....	40
Czechoslovakia.....	89	Portugal.....	16
Danzig.....	2	Queensland.....	12
Denmark.....	36	Rumania.....	19
Egypt.....	9	Russia.....	70
Estonia.....	9	South Australia.....	18
Far Eastern Republic.....	2	Spain.....	30
Finland.....	13	Sweden.....	74
France.....	170	Switzerland.....	64
Germany.....	295	Tasmania.....	5
Great Britain and Ireland.....	333	Union of South Africa.....	13
Greece.....	8	Uruguay.....	30
Haiti.....	2	Venezuela.....	7
Hungary.....	31	Victoria.....	39
India.....	52	Western Australia.....	5
Italy.....	96	Yugoslavia.....	18
Japan.....	65		
			2, 223

FOREIGN DEPOSITORIES OF UNITED STATES GOVERNMENTAL DOCUMENTS

In accordance with the terms of a convention concluded at Brussels, March 15, 1886, and under authority granted by Congress in resolutions approved March 2, 1867, and March 2, 1901, there are now sent through exchange channels regularly to depositories abroad 57 full sets of United States official documents and 38 partial sets.

DEPOSITORIES OF FULL SETS

- ARGENTINA: Ministerio de Relaciones Exteriores, Buenos Aires.
 AUSTRALIA: Library of the Commonwealth Parliament, Melbourne.
 AUSTRIA: Bundesamt für Statistik, Schwarzenbergstrasse 5, Vienna I.
 BADEN: Universitäts-Bibliothek, Freiburg. (Depository of the State of Baden.)
 BAVARIA: Staats-Bibliothek, Munich.
 BELGIUM: Bibliothèque Royale, Brussels.
 BRAZIL: Bibliotheca Nacional, Rio de Janeiro.
 BUENOS AIRES: Biblioteca de la Universidad Nacional de La Plata. (Depository of the Province of Buenos Aires.)
 CANADA: Library of Parliament, Ottawa.
 CHILE: Biblioteca del Congreso Nacional, Santiago.

- CHINA: American-Chinese Publication Exchange Department, Shanghai Bureau of Foreign Affairs, Shanghai.
- COLOMBIA: Biblioteca Nacional, Bogotá.
- COSTA RICA: Oficina de Depósito y Canje Internacional de Publicaciones, San José.
- CUBA: Secretaria de Estado (Asuntos Generales y Canje Internacional), Habana.
- CZECHOSLOVAKIA: Bibliothéque de l'Assemblée Nationale, Prague.
- DENMARK: Kongelige Bibliotheket, Copenhagen.
- ENGLAND: British Museum, London.
- FRANCE: Bibliothéque Nationale, Paris.
- GERMANY: Deutsche Reichstags-Bibliothek, Berlin.
- GLASGOW: City Librarian, Mitchell Library, Glasgow.
- GREECE: Bibliothéque Nationale, Athens.
- HAITI: Secrétaire d'Etat des Relations Extérieures, Port au Prince.
- HUNGARY: Hungarian House of Delegates, Budapest.
- INDIA: Imperial Library, Calcutta.
- IRELAND: National Library of Ireland, Dublin.
- ITALY: Biblioteca Nazionale Vittorio Emanuele, Rome.
- JAPAN: Imperial Library of Japan, Tokyo.
- LONDON: London School of Economics and Political Science. (Depository of the London County Council.)
- MANITOBA: Provincial Library, Winnipeg.
- MEXICO: Instituto Bibliográfico, Biblioteca Nacional, Mexico.
- NETHERLANDS: Bibliotheek van de Tweede Kamer der Staten-Generaal, The Hague.
- NEW SOUTH WALES: Public Library of New South Wales, Sydney.
- NEW ZEALAND: General Assembly Library, Wellington.
- NORWAY: Stortingets Bibliothek, Christiania.
- ONTARIO: Legislative Library, Toronto.
- PARIS: Préfecture de la Seine.
- PERU: Biblioteca Nacional, Lima.
- POLAND: Bibliothéque du Ministère des Affaires Etrangères, Warsaw.
- PORTUGAL: Bibliotheca Nacional, Lisbon.
- PRUSSIA: Preussische Staatsbibliothek, Berlin, N. W. 7.
- QUEBEC: Library of the Legislature of the Province of Quebec, Quebec.
- QUEENSLAND: Parliamentary Library, Brisbane.
- RUSSIA: Shipments temporarily suspended.
- SAXONY: Landesbibliothek, Dresden-N.
- SOUTH AUSTRALIA: Parliamentary Library, Adelaide.
- SPAIN: Servicio del Cambio Internacional de Publicaciones, Cuerpo Facultativo de Archiveros, Bibliotecarios y Arqueólogos, Madrid.
- SWEDEN: Kungliga Bibliotheket, Stockholm.
- SWITZERLAND: Bibliothéque Fédérale Centrale, Berne.
- TASMANIA: Parliamentary Library, Hobart.
- TURKEY: Shipments temporarily suspended.
- UNION OF SOUTH AFRICA: State Library, Pretoria, Transvaal.
- URUGUAY: Oficina de Canje Internacional de Publicaciones, Montevideo.
- VENEZUELA: Biblioteca Nacional, Caracas.
- VICTORIA: Public Library of Victoria, Melbourne.
- WESTERN AUSTRALIA: Public Library of Western Australia, Perth.
- WURTEMBERG: Landesbibliothek, Stuttgart.
- YUGOSLAVIA: Ministère des Affaires Etrangères, Belgrade.

DEPOSITORIES OF PARTIAL SETS

ALBERTA: Provincial Library, Edmonton.

ALSACE-LORRAINE: Bibliothèque Universitaire et Régionale de Strasbourg, Strasbourg.

BOLIVIA: Ministerio de Colonización y Agricultura, La Paz.

BRAZIL: Bibliotheca da Assembleia Legislativa do Estado do Rio de Janeiro, Niteroy.

BREMEN: Senatskommission für Reichs- und Auswärtige Angelegenheiten.

BRITISH COLUMBIA: Legislative Library, Victoria.

BRITISH GUIANA: Government Secretary's Office, Georgetown, Demerara.

BULGARIA: Ministère des Affaires Etrangères, Sofia.

CEYLON: Colonial Secretary's Office (Record Department of the Library), Colombo.

ECUADOR: Biblioteca Nacional, Quito.

EGYPT: Bibliothèque Khédiviale, Cairo.

FINLAND: Central Library of the State, Helsingfors.

GUATEMALA: Secretary of the Government, Guatemala.

HAMBURG: Senatskommission für die Reichs- und Auswärtigen Angelegenheiten.

HESSE: Landesbibliothek, Darmstadt.

HONDURAS: Secretary of the Government, Tegucigalpa.

JAMAICA: Colonial Secretary, Kingston.

LATVIA: Ministry of Foreign Affairs, Riga.

LIBERIA: Department of State, Monrovia.

LOURENÇO MARQUEZ: Government Library, Lourenço Marquez.

LÜBECK: President of the Senate.

MADRAS, PROVINCE OF: Chief Secretary to the Government of Madras, Public Department, Madras.

MALTA: Lieutenant Governor, Valetta.

NEW BRUNSWICK: Legislative Library, Fredericton.

NEWFOUNDLAND: Colonial Secretary, St. John's.

NICARAGUA: Superintendente de Archivos Nacionales, Managua.

NOVA SCOTIA: Provincial Secretary of Nova Scotia, Halifax.

PANAMA: Secretaría de Relaciones Exteriores, Panama.

PARAGUAY: Oficina General de Inmigracion, Asuncion.

PRINCE EDWARD ISLAND: Legislative Library, Charlottetown.

RUMANIA: Academia Romana, Bukharest.

SALVADOR: Ministerio de Relaciones Exteriores, San Salvador.

SASKATCHEWAN: Government Library, Regina.

SIAM: Department of Foreign Affairs, Bangkok.

STRAITS SETTLEMENTS: Colonial Secretary, Singapore.

SWITZERLAND: Library of the League of Nations, Palace of Nations, Quai de Lemán, Geneva.

UNITED PROVINCES OF AGRA AND OUDH: Undersecretary to Government, Allahabad.

VIENNA: Bürgermeister-Amt der Stadt Wien.

INTERPARLIAMENTARY EXCHANGE OF OFFICIAL JOURNALS

The interparliamentary exchange is carried on by this institution in behalf of the United States Government in accordance with authority granted in a congressional resolution approved March 4, 1909, the purpose of that resolution being to carry into effect the

provisions of the second convention concluded at Brussels, March 15, 1886, providing for the immediate exchange of the Official Journal, as well as of the parliamentary annals and documents, to which the United States was one of the signatories.

A complete list of the countries now taking part in this exchange is given below, together with the names of the establishments to which the daily issue of the Congressional Record is mailed:

ARGENTINA: Biblioteca del Congreso Nacional, Buenos Aires.

AUSTRALIA: Library of the Commonwealth Parliament, Melbourne.

AUSTRIA: Bibliothek des Nationalrates, Wien I.

BADEN: Universitäts-Bibliothek, Heidelberg.

BELGIUM: Bibliothèque de la Chambre des Représentants, Brussels.

BOLIVIA: Cámara de Diputados, Congreso Nacional, La Paz.

BRAZIL: Bibliotheca do Congresso Nacional, Rio de Janeiro.

BUENOS AIRES: Biblioteca del Senado de la Provincia de Buenos Aires, La Plata.

CANADA:

Library of Parliament, Ottawa.

Clerk of the Senate, Houses of Parliament, Ottawa.

COSTA RICA: Oficina de Depósito y Canje Internacional de Publicaciones, San José.

CUBA:

Biblioteca de la Cámara de Representantes, Habana.

Biblioteca del Senado, Habana.

CZECHOSLOVAKIA: Bibliothèque de l'Assemblée Nationale, Prague.

DENMARK: Rigsdagens Bureau, København.

ESTHONIA: Riigiraamatukogu, Reval.

FRANCE:

Bibliothèque de la Chambre des Députés, au Palais Bourbon, Paris.

Bibliothèque du Sénat, au Palais du Luxembourg, Paris.

GREAT BRITAIN: Library of the Foreign Office, Downing Street, London, S. W. 1.

GREECE: Library of Parliament, Athens.

GUATEMALA: Biblioteca de la Oficina Internacional Centro-Americana, 8a Calle Poniente No. 1, Ciudad de Guatemala.

HONDURAS: Biblioteca del Congreso Nacional, Tegucigalpa.

HUNGARY: Bibliothek des Abgeordnetenhauses, Budapest.

ITALY:

Biblioteca della Camera dei Deputati, Palazzo di Monte Citorio, Rome.

Biblioteca del Senato del Regno, Palazzo Madama, Rome.

LIBERIA: Department of State, Monrovia.

NEW SOUTH WALES: Library of Parliament, Sydney.

NEW ZEALAND: General Assembly Library, Wellington.

PERU: Cámara de Diputados, Congreso Nacional, Lima.

POLAND: Monsieur le Ministre des Affaires Etrangères, Warsaw.

PORTUGAL: Bibliotheca do Congresso da Republica, Lisbon.

PRUSSIA: Bibliothek des Abgeordnetenhauses, Prinz-Albrechtstrasse 5, Berlin, S. W. 11.

QUEENSLAND: The Chief Secretary's Office, Brisbane.

RUMANIA: Bibliothèque de la Chambre des Députés, Bukharest.

RUSSIA: Sendings temporarily suspended.

SPAIN:

Biblioteca del Congreso de los Diputados, Madrid.

Biblioteca del Senado, Madrid.

SWITZERLAND:

Bibliothèque de l'Assemblée Fédérale Suisse, Berne.

Library of the League of Nations, Geneva.

TRANSVAAL: State Library, Pretoria.

UNION OF SOUTH AFRICA: Library of Parliament, Cape Town.

URUGUAY: Biblioteca de la Cámara de Representantes, Montevideo.

VENEZUELA: Cámara de Diputados, Congreso Nacional, Carácas.

WESTERN AUSTRALIA: Library of Parliament of Western Australia, Perth.

YUGOSLAVIA: Library of the Skupshtina, Belgrade.

The total number of copies of daily Congressional Record set aside by law for exchange with foreign legislative bodies is 100. This exchange is at present conducted with 44 establishments.

FOREIGN EXCHANGE AGENCIES

The State Library (Riigiraamatukogu), Reval, has been designated as the exchange agency for Esthonia.

A complete list of the foreign exchange agencies or bureaus will be found below:

ALGERIA, *via* France.

ANGOLA, *via* Portugal.

ARGENTINA: Comisión Protectora de Bibliotecas Populares, Calle Cordoba 931, Buenos Aires.

AUSTRIA: Bundesamt für Statistik Schwarzenbergstrasse 5, Vienna I.

AZORES, *via* Portugal.

BELGIUM: Service Belge des Échanges Internationaux, Rue des Longs-Charlots 46, Brussels.

BOLIVIA: Oficina Nacional de Estadística, La Paz.

BRAZIL: Serviço de Permutações Internacionais, Bibliotheca Nacional, Rio de Janeiro.

BRITISH COLONIES: Crown Agents for the Colonies, London.

BRITISH GUIANA: Royal Agricultural and Commercial Society, Georgetown.

BRITISH HONDURAS: Colonial Secretary, Belize.

BULGARIA: Institutions Scientifiques de S. M. le Roi de Bulgarie, Sofia.

CANARY ISLANDS, *via* Spain.

CHILE: Servicio de Canjes Internacionales, Biblioteca Nacional, Santiago.

CHINA: American-Chinese Publication Exchange Department, Shanghai Bureau of Foreign Affairs, Shanghai.

CHOSEN: Government General, Keijo.

COLOMBIA: Oficina de Canjes Internacionales y Reparto, Biblioteca Nacional, Bogotá.

COSTA RICA: Oficina de Depósito y Canje Internacional de Publicaciones, San José.

CZECHOSLOVAKIA: Service Tchecoslovaque des Échanges Internationaux, Bibliothèque de l'Assemblée Nationale, Prague 1-79.

DANZIG: Stadtbibliothek, Danzig.

DENMARK: Kongelige Danske Videnskabernes Selskab, Copenhagen.

DUTCH GUIANA: Surinaamsche Koloniale Bibliotheek, Paramaribo.

ECUADOR: Ministerio de Relaciones Exteriores, Quito.

- EGYPT: Government Publications Office, Printing Department, Bulaq, Cairo.
- ESTHONIA: State Library, Reval.
- FAR EASTERN REPUBLIC: Teachers' College of the Far Eastern Republic, Vladivostok.
- FINLAND: Delegation of the Scientific Societies of Finland, Helsingfors.
- FRANCE: Service Français des Échanges Internationaux, 110 Rue de Grenelle, Paris.
- GERMANY: Amerika-Institut, Universitätstrasse 8, Berlin, N. W. 7.
- GREAT BRITAIN AND IRELAND: Messrs. Wheldon & Wesley, 2, 3, and 4 Arthur St., New Oxford St., London, W. C. 2.
- GREECE: Bibliothèque Nationale, Athens.
- GREENLAND, *via* Denmark.
- GUATEMALA: Instituto Nacional de Varones, Guatemala.
- HAITI: Secrétaire d'Etat des Relations Extérieures, Port au Prince.
- HONDURAS: Biblioteca Nacional, Tegucigalpa.
- HUNGARY: Dr. Julius Pikler, Fővárosi Telekértéknnylvántartó Hivatal (City Land Valuation Office), Központi Városház, Budapest IV.
- ICELAND, *via* Denmark.
- INDIA: Superintendent of Stationery, Bombay.
- ITALY: Ufficio degli Scambi Internazionali, Biblioteca Nazionale Vittorio Emanuele, Rome.
- JAMAICA: Institute of Jamaica, Kingston.
- JAPAN: Imperial Library of Japan, Tokyo.
- JAVA, *via* Netherlands.
- LATVIA: Ministry of Foreign Affairs, Riga.
- LIBERIA: Bureau of Exchanges, Department of State, Monrovia.
- LITHUANIA: Sent by mail.
- LOURENÇO MARQUEZ, *via* Portugal.
- LUXEMBURG, *via* Belgium.
- MADAGASCAR, *via* France.
- MADEIRA, *via* Portugal.
- MOZAMBIQUE, *via* Portugal.
- NETHERLANDS: Bureau Scientifique Central Néerlandais, Bibliothèque de l'Académie technique, Delft.
- NEW SOUTH WALES: Public Library of New South Wales, Sydney.
- NEW ZEALAND: Dominion Museum, Wellington.
- NICARAGUA: Ministerio de Relaciones Exteriores, Managua.
- NORWAY: Kongelige Norske Frederiks Universitet, Bibliotheket, Christiania.
- PANAMA: Secretaría de Relaciones Exteriores, Panama.
- PARAGUAY: Servicio de Canje Internacional de publicaciones, Sección Consular y de Comercio, Ministerio de Relaciones Exteriores, Asuncion.
- PERU: Oficina de Reparto, Depósito y Canje Internacional de Publicaciones. Ministerio de Fomento, Lima.
- POLAND: Bibliothèque du Ministère des Affaires Étrangères, Warsaw.
- PORTUGAL: Secção de Trocas Internacionais, Bibliotheca Nacional, Lisbon.
- QUEENSLAND: Bureau of Exchanges of International Publications, Chief Secretary's Office, Brisbane.
- ROUMANIA: Institutul Meteorologic Central, Ministerul Agriculturii, Bukharest.
- RUSSIA: Academy of Sciences, Petrograd.
- SALVADOR: Ministerio de Relaciones Exteriores, San Salvador.
- SIAM: Department of Foreign Affairs, Bangkok.
- SOUTH AUSTRALIA: Public Library of South Australia, Adelaide.

SPAIN: Servicio del Cambio Internacional de Publicaciones, Cuerpo Facultativo de Archiveros, Bibliotecarios y Arqueólogos, Madrid.

SUMATRA, *via* Netherlands.

SWEDEN: Kongliga Svenska Vetenskaps Akademien, Stockholm.

SWITZERLAND: Service des Échanges Internationaux, Bibliothèque Fédérale Centrale, Berne.

SYRIA: American University of Beirut.

TASMANIA: Secretary to the Premier, Hobart.

TRINIDAD: Royal Victoria Institute of Trinidad and Tobago, Port-of-Spain.

TUNIS, *via* France.

TURKEY: Shipments temporarily suspended.

UNION OF SOUTH AFRICA: Government Printing Works, Pretoria, Transvaal.

URUGUAY: Oficina de Canje Internacional de Publicaciones, Montevideo.

VENEZUELA: Biblioteca Nacional, Caracas.

VICTORIA: Public Library of Victoria, Melbourne.

WESTERN AUSTRALIA: Public Library of Western Australia, Perth.

YUGOSLAVIA: Académie Royal Serbe des Sciences et des Arts, Belgrade.

Mr. Henry A. Parker and Mr. John S. Pollock were retired August 20, 1922, under the provisions of the governmental retirement act. Mr. Parker was connected with the Institution for 42 years and Mr. Pollock, 44 years.

Respectfully submitted.

C. G. ABBOT,

Assistant Secretary,

In Charge of Library and Exchanges.

DR. CHARLES D. WALCOTT,

Secretary, Smithsonian Institution.

APPENDIX 6

REPORT ON THE NATIONAL ZOOLOGICAL PARK

SIR: I have the honor to submit the following report on the operations of the National Zoological Park for the fiscal year ending June 30, 1923:

Since the expenses of the National Zoological Park, like those of some other activities of the Federal Government, are borne in part by the District of Columbia, the Bureau of the Budget has, with the initiation of the budget law and for purposes of accounting, included the estimates of the park within the District bill. The act making appropriations for the Government of the District of Columbia and other activities chargeable in whole or in part against the revenue of such District, approved June 29, 1922, contained an item of \$125,000 for the regular maintenance of the park. As an addition to the continuing appropriations available from former years for the purchase of land near the Adams Mill Road entrance, there was appropriated by Congress in the second deficiency bill approved January 22, 1923, the sum of \$3,096.34 to complete the sum of \$8,000 necessary for the termination of this purchase. The bill providing for printing and binding, Smithsonian Institution, contained an allotment of \$300 for the National Zoological Park. This was an increase of \$100 over former allotments, which had, during recent years, been insufficient for the needs of the park.

Considerable progress has been made during the year in the work of preparing for use the area between the great flight cage and the main road in the western part of the park. This work was begun seven years ago but was discontinued during the war. Other minor repairs and improvements have been made, and much effort has been expended in beautifying the grounds, particularly in the parts of the park most used by the public. The value of the collection is greater than ever before; more species of animals are on exhibition and the actual number of specimens of all kinds is greater than in any previous year. Attendance records, for the fourth successive year, have exceeded 2,000,000 visitors.

ACCESSIONS

Gifts.—The number of animals presented by friends of the park shows continued and gratifying increase from year to year. During the past year 266 specimens were thus added to the collection. Many

of these are of particular value and, as in the previous year, special mention should be made of important contributions from tropical America.

Hon. Henry D. Baker, American consul at Trinidad, West Indies, and Mr. William J. La Varre, of Georgetown, British Guiana, both continued their gifts of South American animals. Interesting birds, mammals, and reptiles were received from Mr. Baker, and included in the collections made by Mr. La Varre were two fine specimens of the dusky parrot (*Pionus fuscus*), a species of special interest to the park. Mr. Gordon MacCreagh, of New York City, collected and presented a specimen of the Brazilian red ouakari monkey (*Cacajao rubicundus*), a species rarely seen in captivity and never before represented, apparently, in any zoological garden in the United States. Like the other members of its genus this monkey is very difficult to keep, but this specimen presented by Mr. MacCreagh lived in the park from August 25, 1922, until April 24, 1923, a period of eight months. Among other animals from Mr. MacCreagh was a specimen of the matamata turtle (*Chelys fimbriata*).

Dr. William M. Mann, of the Bureau of Entomology, while engaged in work in southern Mexico, collected for the park a number of interesting animals. Of special interest in Doctor Mann's collection are two Mexican spider monkeys, four Maw's turtles, and eight specimens of Petz's paroquet. The turtle and the paroquet are species new to the park records. Dr. C. Bonne, of Moengo, Surinam, presented to the park a fine young tapir; and Mr. C. E. Bergman, of Norfolk, Va., contributed a specimen of the Magellan fox from Chile, a species not before shown in the park.

The Canadian Government, through Hon. J. B. Harkin, Commissioner of Dominion Parks, presented five Rocky Mountain goats from the preserves at Banff, Alberta, and six young great black-backed gulls from Nova Scotia. The Department of Conservation, State of Michigan, through Mr. W. H. Rowett, State warden, contributed a female timber wolf from the Porcupine Mountains, Gogebic County, Mich.

Mr. Victor J. Evans, of Washington, D. C., continuing his active interest in the collection, contributed a number of desirable animals, among them being specimens of the frogmouth (*Podargus strigoides*) and New Guinea fruit pigeon (*Lamprotreron superba*).

Ninety-nine individual donors contributed to the collection during the year. The complete list is as follows:

Miss Ella Abbott, Lansing, Mich., Florida gallinule.

Dr. Arthur A. Allen, Ithaca, N. Y., 8 canvasbacks.

Mr. Frank Amorosa, Washington, D. C., 5 sparrow hawks.

Mr. H. M. Atherton, Washington, D. C., sparrow hawk.

Hon. Henry D. Baker, Trinidad, B. W. I., douroucouli, curassow, snowy egret,
2 American egrets, and 2 South American tortoises.

Mrs. L. B. Batkins, South Richmond, Va., racoon.

Mr. Walter M. Bauman, Washington, D. C., woodchuck.

Mr. C. E. Bergman, Norfolk, Va., Magellan fox.

Mrs. V. L. Blankenship, Richmond, Va., great horned owl.

Dr. C. Bonne, Moengo, Surinam, Brazilian tapir.

Mr. Maurice K. Brady, Washington, D. C., 4 spreading adders.

Dr. E. W. Brandes, Department of Agriculture, Washington, D. C., scarlet
king snake.

Mr. E. O. Breeden, Radford, Va., barn owl.

Mr. Colvin B. Brown, Washington, D. C., alligator.

Canadian Government, through Hon. J. B. Harkin, 5 Rocky Mountain goats
and 6 great black-backed gulls.

Mrs. A. J. Clapp, Washington, D. C., canary.

Miss May S. Clark, Washington, D. C., horned toad.

Mr. Samuel Hopkins Clark, Ellicott City, Md., red fox.

Mr. A. W. Claver, Laurel, Md., golden eagle.

Mr. C. E. Conner, Lewisburg, W. Va., golden eagle.

Mr. W. C. Cox, Washington, D. C., box-turtle.

Rev. Philip Ayers Dales, Washington, D. C., horned toad.

Mrs. Edward R. Davis, Mountain Lake Park, Md., red fox.

Mr. C. Dowling, Washington, D. C., tayra and two boa constrictors.

Sergt. J. J. Doyle, Marine Barracks, Washington, D. C., great horned owl.

Mr. William Driesbach, Washington, D. C., Virginia opossum.

Mr. George Duquette, Bellevue, Md., coyote.

Mr. George Eastment, Washington, D. C., canary.

Mr. Henry Parsons Erwin, Washington, D. C., 2 alligators.

Mr. Victor J. Evans, Washington, D. C., ruffed lemur, Arabian baboon, 2
zebra-ass hybrids, 2 gray spider monkeys, 2 Gould's monitors, 2 western diamond
back rattlers, fruit pigeon, frogmouth, screech owl, ostrich, American egret,
2 shining starlings, and 5 great white herons.

Dr. N. S. Ferris, Washington, D. C., cardinal.

Mr. B. M. Fookes, Washington, D. C., horned toad.

Mrs. Edw. J. Gardiner, Washington, D. C., double yellow-head parrot.

Mr. W. G. Gossom, Haymarket, Va., banded rattlesnake.

Mrs. E. S. Grimsley, Washington, D. C., canary.

Mrs. J. B. Harding, Washington, D. C., 3 painted turtles.

Hon. Warren G. Harding, White House, Washington, D. C., Virginia opossum.

Mrs. Nannie M. Hawkins, Washington, D. C., Virginia opossum.

Prof. A. L. Herrera, Mexico, D. F., Mexico, tree iguana and Mexican gopher
tortoise.

Mr. Otis B. Hinnant, Wilmington, N. C., 6 diamond-back rattlers.

Mrs. John S. Hord, Washington, D. C., black-faced Gouldian finch and 2
Java sparrows.

Mr. Worthington Houghton, Washington, D. C., horned toad.

Commander J. C. Hunsaker, Washington, D. C., 2 Florida raccoons.

Mr. J. Roland Johnston, Bethesda, Md., diamond-back rattler.

Mrs. J. R. Ketner, Washington, D. C., 2 canaries.

Mrs. Sam Kite, Washington, D. C., alligator.

Mr. C. Hubert Kreh, Frederick, Md., copperhead.

Mr. R. R. Lambert, Washington, D. C., muscovy duck.

Mr. W. J. La Varre, jr., Georgetown, British Guiana, coatimundi, 2 capybaras, 2 weeping capuchins, 6 titi monkeys, blue-and-yellow macaw, 2 dusky parrots, and 50 blue-winged parrotlets.

Hon. Gordon Lee, Washington, D. C., barn owl.

Mr. Manoel de Oliveira Lima, Washington, D. C., curió and white-bellied seedeater.

Mrs. F. S. Lincoln, Washington, D. C., 2 alligators.

Mr. H. J. Long, Fallon, Nev., 2 golden eagles.

Mrs. Dangerfield Love, Washington, D. C., 2 strawberry finches.

Mrs. W. D. Lynham, Washington, D. C., canary.

Mr. Gordon MacCreagh, New York City, red ouakari monkey, matamata turtle, and South American tortoise.

Dr. William M. Mann, Washington, D. C., tree porcupine, 2 spider monkeys, 4 Maw's turtles, 4 Central American cooters, lesser white-fronted parrot, 2 San Lucas house finches, and 8 Petz's paroquets.

Dr. C. B. Masson, Washington, D. C., copperhead.

Mr. William Matthews, Washington, D. C., canary.

Mrs. L. E. McLaren, Washington, D. C., alligator.

Mr. R. Mehrlich, Washington, D. C., chameleon.

Mr. John A. Meyers, Washington, D. C., 2 red-shouldered hawks.

Dr. James F. Mitchell, Washington, D. C., marine iguana.

Dr. MacD. Moore, Washington, D. C., black snake.

Mrs. R. L. Myers, Washington, D. C., alligator.

New York Zoological Society, Bronx Park, N. Y., ground hornbill.

North Dakota Fish and Game Commission, through Mr. E. T. Judd, Cando, N. Dak., two Canada geese.

Mr. J. R. Page, jr., Aberdeen, N. C., two spreading adders.

Dr. Theophilus S. Painter, Austin, Tex., two armadillos.

Mr. J. E. Pankin, Washington, D. C., gray parrot.

Mr. H. W. Peck, Washington, D. C., alligator.

Mr. C. Roberts Perkins, Elkton, Md., alligator.

Mrs. Rose Las Pinas, Washington, D. C., sparrow hawk.

Miss Appolonia Ramicy, Washington, D. C., two canaries.

Mr. Harwood E. Reed, Washington, D. C., Java finch.

Mr. Earl D. Reid, Washington, D. C., pilot black snake.

Mr. F. H. Riley, Washington, D. C., great horned owl.

Mr. H. L. Robinson, Washington, D. C., two Cuban parrots.

Mr. W. H. Rowett, Bessemer, Mich., timber wolf.

Lieut. H. Herman Rudolph, Washington, D. C., two ring-necked pheasants.

Mrs. Whitefield Sammis, Washington, D. C., yellow-naped parrot.

Maj. C. R. Sanderson, Washington, D. C., red-and-blue-and-yellow macaw.

Mrs. Samuel Saylor, Washington, D. C., barn owl.

Mrs. N. Scanland, Ballston, Va., American crow.

Mr. William Scheible, Washington, D. C., wood duck.

Capt. T. A. Secor, U. S. M. C., Washington, D. C., Panama titi monkey.

Mr. George Shelton, Indian Head, Md., bald eagle.

Dr. R. W. Shufeldt and Mr. Maurice K. Brady, Washington, D. C., painted turtle, musk turtle, and 2 Pennsylvania musk turtles.

Mr. Maynard Simmons, Washington, D. C., horned toad.

Mr. W. N. Slye, Washington, D. C., alligator.

Mr. Ernest Smoot, Washington, D. C., ring-necked pheasant.

Mrs. Anna P. Stewart, Washington, D. C., 2 canaries.

Mr. P. J. Talbot, Washington, D. C., yellow-naped parrot.

Messrs. Thourez and Smith, Los Angeles, Calif., green guenon.

Mr. Clarence Turner, Latonia, Ky., black bear.

Mr. J. S. Warmbath, Washington, D. C., red-tailed hawk.

Dr. David White, Washington, D. C., alligator.

Mr. C. H. Wilson, Washington, D. C., barred owl.

Mr. Charles H. Zier, Washington, D. C., Virginia opossum.

Births.—During the year 51 mammals were born and 29 birds were hatched in the park. These records include only such as are reared to a reasonable age, no account being made in these published statistics of young that live only a few days. Mammals born include: European bear, 3; lion, 3; dingo, 3; gray wolf, 4; raccoon, 2; mountain goat, 1; tahr, 1; bison, 2; Indian buffalo, 1; guanaco, 2; llama, 2; red deer, 7; American elk, 2; barasingha, 1; Japanese deer, 6; hog deer, 1; Virginia deer, 2; Trinidad agouti, 1; rhesus monkey, 2; mona, 1; rufus-bellied wallaby, 3; great red kangaroo, 1. Birds hatched were of the following species: Mallard, black duck, wood duck, silver pheasant, peafowl, and black-crowned night heron.

Exchanges.—Specimens received in exchange for surplus stock include 27 mammals and 21 birds. Special mention should be made of two Greenland musk oxen imported by way of Norway, the first ever to be shown in the park; two mouflons, the wild sheep of Corsica and Sardinia; a fine male nilgai from India; a clouded leopard, marbled cat (*Felis marmorata*), and fire cat (*Ailurin planiceps*) from Sumatra; a male panda from India; 2 black and 2 fulvous lemurs; and a two-toed sloth. Birds received in exchange include, besides other more common species, 3 kagus, 2 Victoria crowned pigeons, 3 black-head ibises, 2 falcated ducks, and 2 eagle owls.

Purchases.—Among the mammals purchased during the year were 2 Alaska Peninsula bear cubs, 2 Alaskan black-tailed deer, an ocelot, and 2 otters. Birds purchased include some very desirable specimens: 2 Marquesan doves, 2 red-breasted mergansers, 2 sooty shearwaters, 4 wood ibises, and a gannet. A number of more common water birds, cage birds, eagles, and owls, as well as a number of reptiles, were also acquired by purchase.

Transfers.—Among the animals received by transfer from other Government departments special mention should be made of a shipment of 36 specimens of the Laysan finch, collected by Dr. Alexander Wetmore while engaged in work for the Biological Survey, Department of Agriculture, on the island bird reservations west of Hawaii. The Laysan "finch" (*Telespyza cantans*) is a member of an interesting family of birds that is restricted to the Hawaiian Islands. The specimens sent by Doctor Wetmore were all collected on Midway Island. Some wood ducks, canvasbacks, and a collared lizard were also received by transfer from the Biological Survey.

The Bureau of Fisheries, Department of Commerce, donated a collection of 18 snakes of 5 species that were collected by Mr. F. E. Hare at the biological station, Manchester, Iowa.

REMOVALS

Surplus mammals and birds to the number of 66 were sent away during the year in exchange to other zoological gardens. Among these were the following mammals that had been born and reared in the park: Siberian tiger, 4; dingo, 1; red deer, 8; barasingha, 3; hog deer, 2; Rocky Mountain sheep, 1; bison, 1; hippopotamus, 1; Trinidad agouti, 2; rhesus monkey, 1.

A number of animals on deposit were returned to owners.

The death rate has again been kept at a very low mark. Except for the loss of nine kangaroos from necrobacillosis, there has been no evidence of contagion among the animals. Some of the losses of animals long in the collection are as follows: A sandhill crane (*Grus mexicana*) received January 30, 1899, died April 17, 1923, from enteritis, after 24 years, 2 months, and 18 days in the park. The great black-backed gull, "Billy," well known to thousands of park visitors because of his long residence and sociable nature, died April 13, 1923. "Billy" came to the park from Labrador on November 22, 1905, and had thus been on exhibition for 17 years, 4 months, and 22 days. A male of the northern wild cat (*Lynx uinta*) received September 3, 1907, died of old age on December 30, 1922, 15 years, 3 months, and 27 days after his arrival. A female guanaco received January 20, 1908, died of disseminated tumors, after 14 years, 8 months, and 26 days in the park, on October 16, 1922. The South American condor, male, received October 31, 1908, died June 15, 1923, 14 years, 7 months, and 15 days after arrival. The cause of death, apparently, was lead poisoning, the bird having in some manner swallowed a piece of lead of considerable size. A female llama received March 14, 1908, died of anemia, July 25, 1922, after a life of 14 years, 4 months, and 11 days in the park. A male barasingha deer (*Cervus duvaucelii*) received October 1, 1908, died January 10, 1923, 14 years, 3 months, and 9 days after arrival. A female rhea (*Rhea americana*) received October 8, 1909, died May 1, 1923, after 13 years, 6 months, and 23 days in the collection. A female brown macaque (*Macaca speciosa*) received July 30, 1910, died May 26, 1923, of broncho-pneumonia, after a life in the park of 12 years, 9 months, and 26 days. A boatbill heron (*Cochlearius cochlearius*) received September 28, 1910, died from congestion of the lungs, 12 years, 6 months, and 18 days later, on April 15, 1923. The mate of this bird, received with it, is still living. A female Woodhouse's wolf (*Canis frustror*), born in the park April 17, 1911, died at an age of 11 years, 3 months, and 15 days, on August 1, 1922.

Two male Madagascar weavers (*Foudia madagascariensis*), received June 28, 1912, died on September 9 and October 14, 1922, respectively; a record of 10 years, 3 months, and 16 days, for one of the birds.

One of the most serious losses of the year was that of the female whooping crane (*Grus americanus*), which died of aspergillosis on April 16, 1923. The bird had always appeared in good health up to shortly before its death; it was still comparatively young, and had been in the collection since April 13, 1914, a period of nine years and three days. It is perhaps doubtful if this rare species will ever again be on exhibition in the park. Other serious losses include a female Rocky Mountain goat, June 13, 1923, metritis; giant anteater, October 29, 1922; red ouakari monkey (*Cacajao rubicundus*), April 24, 1923; frogmouth, November 1, 1922, tapeworm infestation; and the Indian jabiru, March 29, 1923, from gastroenteritis.

As heretofore, postmortem examinations were made in most cases by the pathological division of the Bureau of Animal Industry. Fifteenth examinations were made by Dr. Adolph H. Schultz, of the Carnegie Institution, Laboratory of Embryology, and one by specialists at St. Elizabeths Hospital, Department of the Interior. The following list shows the results of autopsies, the cases being arranged by groups:

CAUSES OF DEATH

MAMMALS

- Marsupialia: Gastritis, 1; gastroenteritis, 1; necrobacillosis, 9; accident, 2.
- Carnivora: Pneumonia, 1; enteritis, 3; gastroenteritis and parasitism, 1; internal hemorrhage, 1; goitre and internal hemorrhage, 1; no cause found, 1.
- Rodentia: Hypernephroma, 1; disseminated tumor, 1.
- Primates: Broncho-pneumonia, 1; tuberculosis, 1; enteritis, 2; streptococcus infection, 1; internal hemorrhage, 1; congestive apoplexy, 1; cage paralysis, 1; inanition, 1.
- Artiodactyla: Pneumonia and metritis, 1; tuberculosis, 3; pleurisy, 1; enteritis, 1; gastroenteritis, 2; disseminated tumor, 1; malnutrition, 1; anemia, 1; accident, 1.
- Edentata: Pneumonia, 1; pericarditis, 1.

BIRDS

- Ratitæ: Enteritis, 1; accident, 2.
- Ciconiiformes: Congestion of lungs, 1; enteritis, 1; gastroenteritis, 1; no cause found, 3.
- Anseriformes: Tuberculosis, 1; gastritis, 1; enteritis, 1; inflammation of ceca, 1; no cause found, 4.
- Falconiformes: Lead poisoning, 1; no cause found, 1.
- Galliformes: No cause found, 1.
- Gruiformes: Aspergillosis, 2; enteritis, 2.
- Charadriiformes: Tuberculosis, 1; enteritis, 1; no cause found, 1.
- Psittaciformes: Enteritis, 1.
- Coraciiformes: Aspergillosis, 1; tapeworm infestation, 1.
- Passeriformes: No cause found, 1.

A total of 48 specimens—11 mammals, 20 birds, and 17 reptiles—of special scientific value, were transferred after death to the United States National Museum. A number of eggs of rare birds were also transferred to the Museum. At the request of the Carnegie Laboratory of Embryology, Johns Hopkins Medical School, Baltimore, 27 specimens, mostly mammals, were delivered to that institution for anatomical purposes. One mammal was sent to St. Elizabeths Hospital, Washington, D. C., for special study of the brain. A few skins of cage birds were saved for the reference collection at the park.

ANIMALS IN THE COLLECTION JUNE 30, 1923

MAMMALS

MARSUPIALIA

Virginia opossum (<i>Didelphis virginiana</i>)	4
Australian opossum (<i>Trichosurus vulpecula</i>)	2
Flying phalanger (<i>Petaurus breviceps</i>)	8
Brush-tailed rock wallaby (<i>Petrogale penicillata</i>)	2
Rufous-bellied wallaby (<i>Macropus bilardieri</i>)	9
Black-faced kangaroo (<i>Macropus melanops</i>)	2
Wallaroo (<i>Macropus robustus</i>)	2
Red kangaroo (<i>Macropus rufus</i>)	6
Wombat (<i>Phascolomys mitchelli</i>)	1

CARNIVORA

Kadiak bear (<i>Ursus middendorffi</i>)	2
Alaska Peninsula bear (<i>Ursus gyas</i>)	4
Yakutat bear (<i>Ursus dalli</i>)	1
Kidder's bear (<i>Ursus kidderi</i>)	2
European bear (<i>Ursus arctos</i>)	5
Grizzly bear (<i>Ursus horribilis</i>)	1
Apache grizzly (<i>Ursus apache</i>)	1
Himalayan bear (<i>Ursus thibetanus</i>)	1
Black bear (<i>Ursus americanus</i>)	3
Cinnamon bear (<i>Ursus americanus cinnamonomum</i>)	2
Florida bear (<i>Ursus floridanus</i>)	1
Glacier bear (<i>Ursus emmonsii</i>)	1
Sun bear (<i>Helarctos malayanus</i>)	1
Sloth bear (<i>Melursus ursinus</i>)	1
Polar bear (<i>Thalarctos maritimus</i>)	2
Dingo (<i>Canis dingo</i>)	3
Eskimo dog (<i>Canis familiaris</i>)	2
Gray wolf (<i>Canis nubilus</i>)	6
Timber wolf (<i>Canis occidentalis</i>)	1
Texas red wolf (<i>Canis rufus</i>)	1
Coyote (<i>Canis latrans</i>)	4
Red fox (<i>Vulpes fulva</i>)	10
Kit fox (<i>Vulpes velox</i>)	2
Great-eared fox (<i>Otocoryon megalotis</i>)	1
Magellan fox (<i>Cerdocyon magellanicus</i>)	1
Gray fox (<i>Urocyon cinereoargenteus</i>)	3
Cacomistle (<i>Bassariscus astutus</i>)	1
Panda (<i>Ailurus fulgens</i>)	2
Raccoon (<i>Procyon lotor</i>)	19

CARNIVORA—continued

Florida raccoon (<i>Procyon lotor elucius</i>)	2
Gray coatiundi (<i>Nasua narica</i>)	1
Red coatiundi (<i>Nasua nasua</i>)	1
Kinkajou (<i>Potos flavus</i>)	2
Mexican kinkajou (<i>Potos flavus aztecus</i>)	1
Tayra (<i>Tayra barbara</i>)	2
American badger (<i>Taxidea taxus</i>)	1
Florida spotted skunk (<i>Spilogale ambarvalis</i>)	1
Florida otter (<i>Lutra canadensis vaga</i>)	3
Palm civet (<i>Paradoxurus hermaphroditus</i>)	2
Wahlberg's mongoose (<i>Helogale parvula</i>)	1
Aard-wolf (<i>Proteles cristatus</i>)	1
Spotted hyena (<i>Crocuta crocuta</i>)	1
Stripped hyena (<i>Hyæna hyæna</i>)	1
African cheetah (<i>Acinonyx jubatus</i>)	2
Lion (<i>Felis leo</i>)	5
Bengal tiger (<i>Felis tigris</i>)	1
Manchurian tiger (<i>Felis tigris longipilis</i>)	2
Leopard (<i>Felis pardus</i>)	1
East African leopard (<i>Felis pardus suahelica</i>)	1
Jaguar (<i>Felis onca</i>)	1
Brazilian ocelot (<i>Felis pardalis brasiliensis</i>)	2
Snow leopard (<i>Felis uncia</i>)	1
Mexican puma (<i>Felis azteca</i>)	2
Mountain lion (<i>Felis hipposlestes</i>)	1
Canada lynx (<i>Lynx canadensis</i>)	1
Northern wild cat (<i>Lynx uinta</i>)	2
Bay lynx (<i>Lynx rufus</i>)	2
Clouded leopard (<i>Neofelis nebulosa</i>)	1

PINNIPEDIA

California sea-lion (<i>Zalophus californianus</i>)	2
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RODENTIA

Woodchuck (<i>Marmota monax</i>)	3
Dusky marmot (<i>Marmota flaviventris obscura</i>)	1
Prairie-dog (<i>Cynomys ludovicianus</i>)	5

MAMMALS—continued

RODENTIA—continued

Antelope squirrel (<i>Ammospermophilus leucurus</i>)	1
Chipmunk (<i>Eutamias neglectus</i>)	3
Albino squirrel (<i>Sciurus carolinensis</i>)	3
Dusky pocket mouse (<i>Perognathus flavescens perniger</i>)	1
Bailey's pocket mouse (<i>Perognathus baileyi</i>)	1
Kangaroo rat (<i>Dipodomys spectabilis</i>)	2
Ord's kangaroo rat (<i>Perodipus ordii</i>)	2
Montana white-footed mouse (<i>Peromyscus leucopus aridulus</i>)	1
Grasshopper mouse (<i>Onychomys leucogaster</i>)	6
African porcupine (<i>Hystrix africa-australis</i>)	1
Malay porcupine (<i>Acanthion brachyurum</i>)	2
Tree porcupine (<i>Coendou mericanum</i>)	1
Coypu (<i>Myocastor coypus</i>)	2
Central American paca (<i>Cuniculus paca virgatus</i>)	1
Mexican agouti (<i>Dasyprocta mexicana</i>)	1
Sooty agouti (<i>Dasyprocta fuliginosa</i>)	1
Speckled agouti (<i>Dasyprocta punctata</i>)	2
Panama agouti (<i>Dasyprocta punctata isthmica</i>)	1
Azara's agouti (<i>Dasyprocta azarae</i>)	2
Trinidad agouti (<i>Dasyprocta rubrata</i>)	3
Crested agouti (<i>Dasyprocta cristata</i>)	1
Yellow-rumped agouti (<i>Dasyprocta lucifer cayenne</i>)	1
Peruvian guinea pig (<i>Cavia tschudii pallidior</i>)	1
Guinea pig (<i>Cavia porcellus</i>)	5
Capybara (<i>Hydrochærus hydrochæris</i>)	2

LAGOMORPHA

Domestic rabbit (<i>Oryctolagus cuniculus</i>)	15
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EDENTATA

Two-toed sloth (<i>Cholepus didactylus</i>)	1
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PRIMATES

Black lemur (<i>Lemur macaco</i>)	2
Fulvous lemur (<i>Lemur fulvus</i>)	2
Gray spider monkey (<i>Ateles geoffroyi</i>)	2
Mexican spider monkey (<i>Ateles neglectus</i>)	2
Three-banded douroucouli (<i>Aotus trivirgatus</i>)	1
Brown woolly monkey (<i>Lagothrix infumata</i>)	1
White-throated capuchin (<i>Cebus capucinus</i>)	4
Pale capuchin (<i>Cebus unicolor</i>)	2
Weeping capuchin (<i>Cebus apella</i>)	2
Brown capuchin (<i>Cebus fatuellus</i>)	2
Azara's capuchin (<i>Cebus azarae</i>)	1
Tití monkey (<i>Saimiri sciureus</i>)	5
Chacma (<i>Papio porcarius</i>)	1

PRIMATES—continued

Anubis baboon (<i>Papio cynocephalus</i>)	1
East African baboon (<i>Papio ibcanus</i>)	1
Mandrill (<i>Papio sphinx</i>)	1
Drill (<i>Papio leucophæus</i>)	1
Moor macaque (<i>Cynopithecus maurus</i>)	1
Barbary ape (<i>Simia sylvanus</i>)	2
Japanese macaque (<i>Macaca fuscata</i>)	2
Pig-tailed monkey (<i>Macaca nemestrina</i>)	1
Burmese macaque (<i>Macaca andamanensis</i>)	1
Rhesus monkey (<i>Macaca rhesus</i>)	22
Bonnet monkey (<i>Macaca sinica</i>)	1
Crab-eating macaque (<i>Macaca irus</i>)	1
Javan macaque (<i>Macaca mordax</i>)	4
Black mangabey (<i>Cercocebus aterrimus</i>)	1
Sooty mangabey (<i>Cercocebus fuliginosus</i>)	2
Hagenbeck's mangabey (<i>Cercocebus hagenbecki</i>)	1
White-collared mangabey (<i>Cercocebus torquatus</i>)	1
Green guenon (<i>Lasiopyga callitrichus</i>)	2
Vervet guenon (<i>Lasiopyga pygerythra</i>)	2
Mona (<i>Lasiopyga mona</i>)	4
Roloway guenon (<i>Lasiopyga roloway</i>)	1
Chimpanzee (<i>Pan satyrus</i>)	1
Orang-utan (<i>Pongo pygmaeus</i>)	1

ARTIODACTYLA

Wild boar (<i>Sus scrofa</i>)	1
Wart-hog (<i>Phacochoerus æthiopicus</i>)	1
Collared peccary (<i>Pecari angulatus</i>)	2
Hippopotamus (<i>Hippopotamus amphibius</i>)	2
Bactrian camel (<i>Camelus bactrianus</i>)	2
Arabian camel (<i>Camelus dromedarius</i>)	1
Guanaco (<i>Lama guanicoe</i>)	3
Llama (<i>Lama glama</i>)	7
Fallow deer (<i>Dama dama</i>)	5
Axis deer (<i>Axis axis</i>)	3
Hog deer (<i>Hyelaphus porcinus</i>)	7
Sambar (<i>Rusa unicolor</i>)	2
Barasingha (<i>Rucervus duvaucelii</i>)	6
Burmese deer (<i>Rucervus eldii</i>)	1
Japanese deer (<i>Sika nippon</i>)	19
Red deer (<i>Cervus elaphus</i>)	12
Kashmir deer (<i>Cervus hanglu</i>)	2
Bedford deer (<i>Cervus xanthopygus</i>)	6
American elk (<i>Cervus canadensis</i>)	7
Virginia deer (<i>Odocoileus virginianus</i>)	9
Panama deer (<i>Odocoileus chiriquensis</i>)	1
Black-tailed deer (<i>Odocoileus columbianus</i>)	2
Blesbok (<i>Damaliscus albifrons</i>)	2
White-tailed gnu (<i>Connochaetes gnou</i>)	1
Brindled gnu (<i>Connochaetes taurinus</i>)	1
Lechwe (<i>Onotragus lechwe</i>)	1
Sable antelope (<i>Egocerus niger</i>)	1
Indian antelope (<i>Antelope cervicapra</i>)	3
Nilgai (<i>Boselaphus tragocamelus</i>)	3
East African eland (<i>Taurotragus oryx livingstonii</i>)	2

MAMMALS—continued

ARTIODACTYLA—continued •

Tahr (<i>Hemitragus jemlahicus</i>)-----	5
Mountain goat (<i>Oreamnos americanus</i>)-----	5
Aoudad (<i>Ammotragus lervia</i>)-----	2
Rocky Mountain sheep (<i>Ovis canadensis</i>)-----	4
Arizona mountain sheep (<i>Ovis canadensis gaillardi</i>)-----	1
Mouflon (<i>Ovis musimon</i>)-----	2
Barbados sheep (<i>Ovis aries</i>)-----	2
Greenland musk ox (<i>Ovibos moschatus wardi</i>)-----	2
Zebu (<i>Bos indicus</i>)-----	1
Yak (<i>Poëphagus grunniens</i>)-----	5
American bison (<i>Bison bison</i>)-----	13
Indian buffalo (<i>Bubalus bubalis</i>)-----	3

PERISSODACTYLA

Malay tapir (<i>Tapirus indicus</i>)-----	1
Brazilian tapir (<i>Tapirus terrestris</i>)--	2
Grant's zebra (<i>Equus quagga granti</i>)--	1
Grevy's zebra (<i>Equus grevyi</i>)-----	1
Zebra-horse hybrid (<i>Equus grevyi caballus</i>)-----	1
Zebra-ass hybrid (<i>Equus grevyi-asinus</i>)-----	3

PROBOSCIDEA

Abyssinian elephant (<i>Loxodonta africana aegyptis</i>)-----	1
Sumatran elephant (<i>Elephas sumatranus</i>)-----	2

BIRDS

RATITÆ

South African ostrich (<i>Struthio australis</i>)-----	6
Smallland ostrich (<i>Struthio molybdophanes</i>)-----	2
Nubian ostrich (<i>Struthio camelus</i>)-----	2
Rhea (<i>Rhea americana</i>)-----	1
Slater's cassowary (<i>Casuarus philipi</i>)-----	1
Emu (<i>Dromicetus novæhollandiæ</i>)-----	2

PROCELLARIIFORMES

Sooty shearwater (<i>Puffinus griseus</i>)----	1
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CICONIIFORMES

American white pelican (<i>Pelecanus erythrorhynchos</i>)-----	7
European white pelican (<i>Pelecanus onocrotalus</i>)-----	2
Roseate pelican (<i>Pelecanus roseus</i>)-----	2
Australian pelican (<i>Pelecanus conspicillatus</i>)-----	2
Brown pelican (<i>Pelecanus occidentalis</i>)-----	9
Water-turkey (<i>Anhinga anhinga</i>)-----	1
Florida cormorant (<i>Phalacrocorax auritus floridanus</i>)-----	4
Gannet (<i>Sula bassana</i>)-----	1
Great white heron (<i>Ardea occidentalis</i>)-----	7
Goliath heron (<i>Ardea goliath</i>)-----	1
American egret (<i>Casmerodius egretta</i>)-----	5
Snowy egret (<i>Egretta candidissima</i>)-----	1
Black-crowned night heron (<i>Nycticorax nycticorax naevius</i>)-----	45
Boatbill (<i>Cochlearius cochlearius</i>)-----	1
White stork (<i>Ciconia ciconia</i>)-----	2
Black stork (<i>Ciconia nigra</i>)-----	1
Lesser adjutant (<i>Leptoptilus javanicus</i>)-----	1
Wood ibis (<i>Myoteria americana</i>)-----	3
Straw-necked ibis (<i>Carphibis spinicollis</i>)-----	1

CICONIIFORMES—continued

Sacred ibis (<i>Threskiornis æthiopicus</i>)--	3
Black-headed ibis (<i>Threskiornis melanoccephalus</i>)-----	3
Australian ibis (<i>Threskiornis strictipennis</i>)-----	2
White ibis (<i>Guara alba</i>)-----	11
Scarlet ibis (<i>Guara rubra</i>)-----	4
Roseate spoonbill (<i>Ajaja ajaja</i>)-----	2
European flamingo (<i>Phœnicopterus roseus</i>)-----	1

ANSERIFORMES

Red-breasted merganser (<i>Mergus serrator</i>)-----	2
Mallard (<i>Anas platyrhynchos</i>)-----	16
Black duck (<i>Anas rubripes</i>)-----	19
Australian black duck (<i>Anas superciliosa</i>)-----	2
Gadwall (<i>Chaulelasmus streperus</i>)-----	3
Falcated duck (<i>Eunetta falcata</i>)-----	2
European wigeon (<i>Mareca penelope</i>)--	5
Baldpate (<i>Mareca americana</i>)-----	4
Green-winged teal (<i>Nettion carolinense</i>)	15
European teal (<i>Nettion crecca</i>)-----	10
Baikal teal (<i>Nettion formosum</i>)-----	6
Blue-winged teal (<i>Querquedula discors</i>)-----	9
Garganey (<i>Querquedula querquedula</i>)--	6
Cinnamon teal (<i>Querquedula cyanoptera</i>)-----	1
Shoveller (<i>Spatula clypeata</i>)-----	4
Pintail (<i>Dafila acuta</i>)-----	8
Wood duck (<i>Aix sponsa</i>)-----	10
Mandarin duck (<i>Dendronessa galericulata</i>)-----	13
Canvas-back (<i>Marila valisineria</i>)-----	13
European pochard (<i>Marila ferina</i>)-----	4
Redhead (<i>Marila americana</i>)-----	14
Ring-necked duck (<i>Marila collaris</i>)-----	1
Tufted duck (<i>Marila fuligula</i>)-----	4
Lesser scaup duck (<i>Marila affinis</i>)-----	5
Greater scaup duck (<i>Marila marila</i>)-----	11
White-eyed duck (<i>Marila nyroca</i>)-----	1

BIRDS—continued

ANSERIFORMES—continued

Rosy-billed pochard (<i>Metopiana pepo-</i> <i>saca</i>) -----	4
Egyptian goose (<i>Chenaloepæ ægyptia-</i> <i>cus</i>) -----	3
Upland goose (<i>Chloëphaga leucoptera</i>)--	1
Hawaiian goose (<i>Nesochen sandvicens-</i> <i>sis</i>) -----	2
Snow goose (<i>Chen hyperboreus</i>)-----	2
Greater snow goose (<i>Chen hyperboreus</i> <i>nivalis</i>) -----	2
Blue goose (<i>Chen cærulescens</i>)-----	7
White-fronted goose (<i>Anser albifrons</i>)--	4
American white-fronted goose (<i>Anser</i> <i>albifrons gambeli</i>)-----	3
Bean goose (<i>Anser fabalis</i>)-----	2
Bar-headed goose (<i>Eulabeia indica</i>)--	2
Canada goose (<i>Branta canadensis</i>)--	11
Hutchins's goose (<i>Branta canadensis</i> <i>hutchinsii</i>) -----	7
Cackling goose (<i>Branta canadensis</i> <i>minima</i>) -----	2
Brant (<i>Branta bernicla glaucogastra</i>)--	10
Barnacle goose (<i>Branta leucopsis</i>)-----	7
Spur-winged goose (<i>Plectropterus gam-</i> <i>bensis</i>) -----	2
Muscovy duck (<i>Cairina moschata</i>)-----	1
Pied goose (<i>Anseranas semipalmata</i>)--	2
Black-bellied tree duck (<i>Dendrocygna</i> <i>autumnalis</i>) -----	6
Eyton's tree duck (<i>Dendrocygna</i> <i>eytoni</i>) -----	4
White-faced tree duck (<i>Dendrocygna</i> <i>viduata</i>) -----	1
Mute swan (<i>Cygnus gibbus</i>)-----	2
Whistling swan (<i>Olor columbianus</i>)--	1
Black swan (<i>Oenopsis atrata</i>)-----	2

FALCONIFORMES

California condor (<i>Gymnogyps cali-</i> <i>fornianus</i>) -----	3
Turkey vulture (<i>Cathartes aura</i>)-----	3
Black vulture (<i>Coragyps urubu</i>)-----	1
King vulture (<i>Sarcoramphus papa</i>)-----	2
Secretary bird (<i>Sagittarius serpen-</i> <i>tarius</i>) -----	1
Griffon vulture (<i>Gyps fulvus</i>)-----	1
African black vulture (<i>Torgos trache-</i> <i>liotus</i>) -----	1
Cinereous vulture (<i>Aegyptius mona-</i> <i>chus</i>) -----	2
Caracara (<i>Polyborus cheriway</i>)-----	2
Wedge-tailed eagle (<i>Uroaëtus audax</i>)--	2
Golden eagle (<i>Aquila chrysaëtus</i>)-----	7
White-bellied sea eagle (<i>Ouncuma leu-</i> <i>coaster</i>) -----	2
Bald eagle (<i>Haliaëtus leucocephalus</i>)--	13
Alaskan bald eagle (<i>Haliaëtus leuco-</i> <i>cephalus alascanus</i>) -----	3
Broad-winged hawk (<i>Buteo platyp-</i> <i>terus</i>) -----	1
Red-shouldered hawk (<i>Buteo line-</i> <i>atus</i>) -----	3
Red-tailed hawk (<i>Buteo borealis</i>)-----	6
Sparrow hawk (<i>Falco sparverius</i>)-----	7

GALLIFORMES

Curassow (<i>Oraæ daubentoni</i>)-----	1
Razor-billed curassow (<i>Mitu mitu</i>)---	2
Penelope (<i>Penelope boliviana</i>)-----	1
Guan (<i>Ortalis albigentris</i>)-----	1
Chachalaca (<i>Ortalis vetula</i>)-----	1
Peafowl (<i>Pavo cristatus</i>)-----	30
Peacock pheasant (<i>Polyplectron bical-</i> <i>caratum</i>) -----	1
Silver pheasant (<i>Gennæus nycthe-</i> <i>merus</i>) -----	5
Ring-necked pheasant (<i>Phasianus tor-</i> <i>quatus</i>) -----	10
Bobwhite (<i>Colinus virginianus</i>)-----	1
Gambel's quail (<i>Lophortyx gambelii</i>)--	2
Valley quail (<i>Lophortyx californica</i> <i>vallicola</i>) -----	1

GRUIFORMES

East Indian gallinule (<i>Porphyrio</i> <i>calvus</i>) -----	5
Black-tailed moor-hen (<i>Microtribonyx</i> <i>ventralis</i>) -----	2
American coot (<i>Fulica americana</i>)---	1
South Island weka rail (<i>Ocydromus</i> <i>australis</i>) -----	3
Short-winged weka (<i>Ocydromus brachy-</i> <i>pterus</i>) -----	2
Earl's weka (<i>Ocydromus earli</i>)-----	1
Sandhill crane (<i>Grus mexicana</i>)-----	1
Little brown crane (<i>Grus canadensis</i>)--	5
White-necked crane (<i>Grus leucau-</i> <i>chen</i>) -----	1
Indian white crane (<i>Grus leucoger-</i> <i>anus</i>) -----	1
Lilford's crane (<i>Grus lilfordi</i>)-----	2
Sarus crane (<i>Grus collaris</i>)-----	1
Australian crane (<i>Grus rubicunda</i>)---	2
Demoiselle crane (<i>Anthropoides virgo</i>)--	4
Crowned crane (<i>Balearica pavonina</i>)--	1
White-backed trumpeter (<i>Psophia leu-</i> <i>coptera</i>) -----	2
Kagu (<i>Rhynchoceros jubatus</i>)-----	4

CHARADRIIFORMES

Lapwing (<i>Vanellus vanellus</i>)-----	3
Yellow-wattled lapwing (<i>Lobivanellus</i> <i>indicus</i>) -----	1
Pacific gull (<i>Gabianus pacificus</i>)-----	2
Great black-backed gull (<i>Larus mari-</i> <i>nus</i>) -----	5
Herring gull (<i>Larus argentatus</i>)-----	3
Silver gull (<i>Larus novæhollandiæ</i>)-----	16
Laughing gull (<i>Larus atricilla</i>)-----	2
Victoria crowned pigeon (<i>Goura vic-</i> <i>toria</i>) -----	2
Australian crested pigeon (<i>Ocyphaps</i> <i>lophotes</i>) -----	5
Bronze-wing pigeon (<i>Phaps chalcop-</i> <i>tera</i>) -----	3
Marquesan dove (<i>Gallicolumba rubes-</i> <i>cens</i>) -----	2
Wonga-wonga pigeon (<i>Leucosarcia pi-</i> <i>cata</i>) -----	3
Wood pigeon (<i>Columba palumbus</i>)---	7
Mourning dove (<i>Zenaidura macroura</i>)--	2

BIRDS—continued

CHARADRIIFORMES—continued

Necklaced dove (<i>Spilopelia tigrina</i>)	4
Zebra dove (<i>Geopelia striata</i>)	3
Bar-shouldered dove (<i>Geopelia humeralis</i>)	1
Inca dove (<i>Scardafella inca</i>)	2
Cuban ground dove (<i>Chamepelia passerina aflavida</i>)	1
Green-winged dove (<i>Chalcophaps indica</i>)	1
New Guinea green dove (<i>Chalcophaps chrysochlora</i>)	3
Ringed turtle-dove (<i>Streptopelia risoria</i>)	1
Fruit pigeon (<i>Lamprolaima superba</i>)	1

CUCULIFORMES

Road runner (<i>Geococcyx californianus</i>)	1
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PSITTACIFORMES

Kea (<i>Nestor notabilis</i>)	4
Cockateel (<i>Calopsitta novae-hollandiae</i>)	1
Roseate cockatoo (<i>Kakatoe roseicapilla</i>)	18
Bare-eyed cockatoo (<i>Kakatoe gymnotis</i>)	1
Leadbeater's cockatoo (<i>Kakatoe leadbeateri</i>)	2
White cockatoo (<i>Kakatoe alba</i>)	2
Sulphur-crested cockatoo (<i>Kakatoe galerita</i>)	9
Great red-crested cockatoo (<i>Kakatoe moluccensis</i>)	1
Cassin's macaw (<i>Ara auricollis</i>)	1
Mexican green macaw (<i>Ara mexicana</i>)	2
Blue-and-yellow macaw (<i>Ara arauna</i>)	3
Red-and-blue-and-yellow macaw (<i>Ara macao</i>)	7
Hahn's macaw (<i>Diopsittaca hahni</i>)	1
White-eyed paroquet (<i>Aratinga leucophthalmus</i>)	1
Petz's paroquet (<i>Eupsittula canicularis</i>)	8
Golden-crowned paroquet (<i>Eupsittula aurea</i>)	3
Weddell's paroquet (<i>Eupsittula weddellii</i>)	4
Blue-winged parrotlet (<i>Psittacula passerina</i>)	14
Yellow-winged paroquet (<i>Tirica virescens</i>)	1
Golden paroquet (<i>Brotogeris chrysomela</i>)	5
Tovi paroquet (<i>Brotogeris jugularis</i>)	3
Orange-winged paroquet (<i>Brotogeris chiriri</i>)	5
Yellow-naped parrot (<i>Amazona auro-pallata</i>)	5
Mealy parrot (<i>Amazona farinosa</i>)	1
Orange-winged parrot (<i>Amazona amazonica</i>)	4
Blue-fronted parrot (<i>Amazona aestiva</i>)	1
Red-crowned parrot (<i>Amazona viridigenalis</i>)	6

PSITTACIFORMES—continued

Double yellow-lead parrot (<i>Amazona oratrix</i>)	9
Yellow-headed parrot (<i>Amazona ochrocephala</i>)	4
Festive parrot (<i>Amazona festiva</i>)	5
Lesser white-fronted parrot (<i>Amazona albifrons nana</i>)	1
Santo Domingo parrot (<i>Amazona ventralis</i>)	2
Cuban parrot (<i>Amazona leucoccephala</i>)	2
Maximilian's parrot (<i>Pionus maximiliani</i>)	1
Dusky parrot (<i>Pionus fuscus</i>)	1
Blue-headed parrot (<i>Pionus menstruus</i>)	3
Amazonian calque (<i>Pionites xanthomeria</i>)	7
Short-tailed parrot (<i>Graydidascalus brachyurus</i>)	1
Gray parrot (<i>Psittacus erithacus</i>)	1
Lesser vasa parrot (<i>Coracopsis nigra</i>)	1
Greater vasa parrot (<i>Coracopsis vasa</i>)	1
Pennant's paroquet (<i>Platycercus elegans</i>)	1
Rosella paroquet (<i>Platycercus eximius</i>)	1
Black-tailed paroquet (<i>Polytelis melanara</i>)	2
King paroquet (<i>Aprosmictus cyanopygius</i>)	2
Ring-necked paroquet (<i>Conurus torquatus</i>)	1
Nepalese paroquet (<i>Conurus nepalensis</i>)	1
Grass paroquet (<i>Melopsittacus undulatus</i>)	27

CORACIFORMES

Giant kingfisher (<i>Dacelo gigas</i>)	2
Yellow-billed hornbill (<i>Lophoceros leucomelas</i>)	2
Barred owl (<i>Strix varia</i>)	7
Snowy owl (<i>Nyctea nyctea</i>)	1
Screech owl (<i>Otus asio</i>)	2
Choliba screech owl (<i>Otus choliba</i>)	1
Great horned owl (<i>Bubo virginianus</i>)	8
Eagle owl (<i>Bubo bubo</i>)	1
American barn owl (<i>Tyto perlata pratincola</i>)	6
Ariel toucan (<i>Ramphastos ariel</i>)	1

PASSERIFORMES

Cock of the rock (<i>Rupicola rupicola</i>)	1
Silver-eared hill-tit (<i>Mesia argentauris</i>)	2
Red-billed hill-tit (<i>Liothrix luteus</i>)	7
Black-gorgeted laughing-thrush (<i>Garulax pectoralis</i>)	2
White-eared bulbul (<i>Otocompsa leucotis</i>)	3
European blackbird (<i>Turdus merula</i>)	2
Piping crow-shrike (<i>Gymnorhina tibicen</i>)	2
Satin bower-bird (<i>Ptilonorhynchus violaceus</i>)	1

BIRDS—continued

PASSERIFORMES—continued

European raven (<i>Corvus corax</i>)-----	1
Australian crow (<i>Corvus coronoides</i>)--	1
American crow (<i>Corvus brachyrhyn-</i> <i>chos</i>)-----	1
Jackdaw (<i>Corvus monedula</i>)-----	1
Yucatan jay (<i>Oissilophya yucatanica</i>)--	1
Blue jay (<i>Cyanocitta cristata</i>)-----	3
Green jay (<i>Xanthoeca luxuosa</i>)-----	1
Australian gray jumper (<i>Struthidea</i> <i>cinerea</i>)-----	1
Starling (<i>Sturnus vulgaris</i>)-----	9
Shining starling (<i>Lamprocorax metal-</i> <i>licus</i>)-----	4
Laysan finch (<i>Telespyza cantans</i>)-----	36
Crimson tanager (<i>Ramphocelus dimi-</i> <i>diatus</i>)-----	1
Blue tanager (<i>Thraupis cana</i>)-----	1
Paradise whydah (<i>Steganura para-</i> <i>disea</i>)-----	1
Shaft-tailed whydah (<i>Tetrænura regia</i>)--	2
Napoleon weaver (<i>Pyromelana afra</i>)--	1
Red-billed weaver (<i>Quelea quelea</i>)-----	1
Madagascar weaver (<i>Foudia madagas-</i> <i>cariensis</i>)-----	1
Fire finch (<i>Lagonosticta senegala</i>)-----	1
Strawberry finch (<i>Amandava aman-</i> <i>dava</i>)-----	8
Nutmeg finch (<i>Munia punctulata</i>)-----	5
White-headed nun (<i>Munia maja</i>)-----	4
Black-headed nun (<i>Munia atricapilla</i>)--	1
Java finch (<i>Munia oryzivora</i>)-----	4
White Java finch (<i>Munia oryzivora</i>)--	2
Masked grassfinch (<i>Poëphila perso-</i> <i>nata</i>)-----	7
Black-faced Gouldian finch (<i>Poëphila</i> <i>gouldiae</i>)-----	4
Red-faced Gouldian finch (<i>Poëphila</i> <i>mirabilis</i>)-----	5
Diamond finch (<i>Steganopleura guttata</i>)--	5
Zebra finch (<i>Tænipygia castanotis</i>)-----	20
Cut-throat finch (<i>Amadina fasciata</i>)--	3
Vera Cruz red-wing (<i>Agelaius phæni-</i> <i>ceus richmondi</i>)-----	1
Purple grackle (<i>Quiscalus quiscula</i>)--	3
Greenfinch (<i>Chloris chloris</i>)-----	3
European goldfinch (<i>Carduelis car-</i> <i>duellii</i>)-----	4
Bramblefinch (<i>Fringilla montifringilla</i>)--	5
European siskin (<i>Spinus spinus</i>)-----	1
Mexican goldfinch (<i>Astragalinus psal-</i> <i>tria mexicanus</i>)-----	1
House finch (<i>Carpodacus mexicanus</i> <i>frontalis</i>)-----	2
San Lucas house finch (<i>Carpodacus</i> <i>mexicanus ruberrimus</i>)-----	2
Canary (<i>Serinus canarius</i>)-----	22
Green singing finch (<i>Serinus icterus</i>)--	1
Slate-colored junco (<i>Junco hyemalis</i>)--	2
White-throated sparrow (<i>Zonotrichia</i> <i>albicollis</i>)-----	3
Song sparrow (<i>Melospiza melodia</i>)-----	1
San Diego song sparrow (<i>Melospiza</i> <i>melodia cooperi</i>)-----	3
Saffron finch (<i>Sicalia flaveola</i>)-----	1

PASSERIFORMES—continued

Seed-eater (<i>Sporophila gutturalis</i>)-----	2
Nonpareil (<i>Passerina ciris</i>)-----	5
Cardinal (<i>Cardinalis cardinalis</i>)-----	1
REPTILES	
Alligator (<i>Alligator mississippiensis</i>)--	68
Marine iguana (<i>Amblyrhynchus cris-</i> <i>tatus</i>)-----	1
Gila monster (<i>Heloderma suspectum</i>)--	6
Gould's monitor (<i>Varanus gouldii</i>)-----	3
Rock python (<i>Python molurus</i>)-----	2
Regal python (<i>Python reticulatus</i>)-----	1
Diamond python (<i>Python spilotes</i>)-----	4
Anaconda (<i>Eunectes murinus</i>)-----	2
Boa constrictor (<i>Constrictor constrictor</i>)--	5
Spreading adder (<i>Heterodon contor-</i> <i>trix</i>)-----	7
Blacksnake (<i>Coluber constrictor</i>)-----	7
Blue racer (<i>Coluber constrictor flavi-</i> <i>ventris</i>)-----	7
Chicken snake (<i>Elaphe quadrivittata</i>)--	1
Corn snake (<i>Elaphe guttata</i>)-----	1
Pilot blacksnake (<i>Elaphe obsoleta</i>)-----	1
Pine snake (<i>Pituophis melanoleucus</i>)--	4
Bull-snake (<i>Pituophis sayi</i>)-----	3
Water snake (<i>Natrix sipedon</i>)-----	4
Western water snake (<i>Natrix sipedon</i> <i>fasciata</i>)-----	2
Garter snake (<i>Thamnophis sirtalis</i>)-----	9
Moccasin (<i>Agkistrodon piscivorus</i>)-----	2
Copperhead (<i>Agkistrodon mokasen</i>)-----	2
Banded rattlesnake (<i>Crotalus horridus</i>)--	1
Diamond-back rattler (<i>Crotalus ada-</i> <i>mantus</i>)-----	3
Snapping turtle (<i>Chelydra serpentina</i>)--	7
Rossignol's snapping turtle (<i>Chelydra</i> <i>rossignonii</i>)-----	41
Maw's turtle (<i>Dermatemys mawii</i>)-----	1
Musk-turtle (<i>Kinosternon odoratum</i>)--	4
South American musk-turtle (<i>Kino-</i> <i>sternon scorioides</i>)-----	1
Pennsylvania musk-turtle (<i>Kinosternon</i> <i>subrubrum</i>)-----	5
Wood turtle (<i>Glemmys insculpta</i>)-----	2
South American terrapin (<i>Nicoria</i> <i>punctularia</i>)-----	1
Painted turtle (<i>Chrysemys picta</i>)-----	7
Cooter (<i>Pseudemys scripta</i>)-----	3
Central American cooter (<i>Pseudemys</i> <i>ornata</i>)-----	1
Box-tortoise (<i>Terrapene carolina</i>)-----	3
Gopher tortoise (<i>Gopherus polyphemus</i>)--	2
Mexican gopher tortoise (<i>Gopherus</i> <i>berlandieri</i>)-----	4
Desert tortoise (<i>Gopherus agassizii</i>)-----	1
Duncan Island tortoise (<i>Testudo ephip-</i> <i>pium</i>)-----	1
Indefatigable Island tortoise (<i>Testudo</i> <i>porteri</i>)-----	1
Albemarle Island tortoise (<i>Testudo</i> <i>vicina</i>)-----	2
South American tortoise (<i>Testudo</i> <i>denticulata</i>)-----	7

STATEMENT OF THE COLLECTION

Accessions during the year

	Mammals	Birds	Reptiles	Total
Presented.....	47	153	66	266
Born and hatched in National Zoological Park.....	51	29		80
Received in exchange.....	27	21		48
Purchased.....	15	66	27	108
Transferred from other Government departments.....		40	19	59
Captured.....			1	1
Deposited.....	12	6	32	50
Total.....	152	315	145	612

SUMMARY

Animals on hand July 1, 1922.....	1, 681
Accessions during the year.....	612
Total animals handled.....	2, 293
Deduct loss (by exchange, death, and return of animals on deposit).....	525
Animals on hand June 30, 1923.....	1, 768

Class	Species	Individuals
Mammals.....	184	493
Birds.....	271	1, 081
Reptiles.....	43	194
Total June 30, 1923.....	498	1, 768

The number of species on exhibition on June 30 is 16 more, and the total number of animals is 87 more than in any previous year.

VISITORS

The total number of visitors to the park, for the fiscal year, as determined by count and estimate, was 2,393,428. This is 229,174 above the official record for 1922, and makes the fourth year in succession that the attendance has exceeded 2,000,000. The greatest attendance in any one month was 330,700 in May, 1923.

The attendance by months was as follows:

1922	1923
July..... 192, 400	January..... 57, 452
August..... 216, 500	February..... 80, 558
September..... 251, 800	March..... 232, 715
October..... 215, 500	April..... 275, 052
November..... 148, 400	May..... 330, 700
December..... 87, 051	June..... 304, 900

Schools, classes, and other organizations visiting the park during the year numbered 171, with a total of 14,185 individuals.

IMPROVEMENTS

The complete reconstruction of the wolf and fox dens below the sea lion pool was finished early in the year. The quarters for these animals are now much more comfortable and sanitary than before and immensely improved in appearance. The outdoor cages for rhesus and other monkeys were all repaired, covered with new wire, provided with suitable water and sewer facilities, and generally put into first-class condition. Repairs were made to the ostrich enclosure, safety guards of electrically welded wire were placed along the fence bordering the walk in front of the main bear dens, and numerous minor repairs were made to cages and enclosures. In so far as was possible with the limited funds, necessary painting was done.

The principal construction for the year, however, has been the continuation of work on the recently graded area in the west-central part of the park, between the great flight cage and the hospital building. This work was commenced seven years ago, but was discontinued during the war. It is greatly to be hoped that it may be completed during the current year. After building a new road from the hospital to the scales, near the Rocky Mountain sheep inclosure, over the edge of the fill previously made, the old winding road was abandoned and there was available a large area of flat ground suitable for paddocks. Four extra large yards were designed along the automobile road, where species commonly kept in breeding herds may be shown. One yard has been especially designed for Rocky Mountain goats and a miniature mountain of flint bowlders has been constructed within it. The other large yards bordering the automobile road have been prepared for red deer, barasingha deer, and Japanese deer. On the south side, bordering the walk passing the great flight cage for birds, are seven paddocks with shelters, designed especially for Indian buffaloes, tahr goats, aoudads, axis deer, and similar species. The water-buffalo yard has been provided with a large tank for bathing, and the tahr and aoudad yards with large rock piles. The axis deer shelter includes a closed room of commodious size for breeding females, as this species commonly brings forth the young in winter, when the weather out of doors is unfavorable for young fawns. Passing directly through the center of this system of yards from east to west is a service road along which all of the shelter houses have been built. This system places the retreats for animals at the rear of each yard, away from the public, and, after proper planting, makes the buildings comparatively inconspicuous. It also simplifies care and the shifting or transfer of animals without actual capture. At the end of the

year the yards and shelters were practically completed; the principal work remaining undone includes sidewalks, parking space, tree boxes, guard rails, and other minor accessories.

ALTERATIONS OF BOUNDARIES

With the approval on January 23, 1923, of the second deficiency bill, there was available \$8,000 for the purchase of the strip of land between the park and Adams Mill Road between Ontario Road and Clydesdale Place. The completion of this purchase adds about 8,000 feet of land to the area of the park and protects the entrance at Adams Mill Road from unsightly development on one side. A new danger that threatens the beauty of this entrance way to the park has, however, most unexpectedly arisen. On March 4, 1923, an act of Congress was passed and approved dissolving the cemetery association controlling the burial ground bordering the Zoological Park on the south between Adams Mill Road and Rock Creek. The trustees named in the bill are authorized to transfer the bodies interred in this old cemetery and to sell the land. The permanent highways plan of the District of Columbia shows a proposed road across this property from Adams Mill Road to Calvert Street Bridge. It will be necessary in order to protect this section of the park, especially the beautiful roadway leading down from the Adams Mill Road entrance, to acquire that portion of the cemetery lying between this proposed roadway and the park boundary. It has been suggested that the permanent highways plan be modified, and that the proposed road across the old cemetery be made from Adams Mill Road at the corner of the Zoological Park to join Waterside Drive at Calvert Street Bridge. This would greatly reduce the area to be purchased for park purposes and amply protect the interests of the public.

IMPORTANT NEEDS

Restaurant.—As pointed out in recent reports, a suitable restaurant building remains the most urgent need of the park. The old refreshment stand was constructed many years ago of the cheapest materials. At the present time it is in a bad condition and is wholly inadequate to serve the needs of the public. The refreshment booth at Connecticut Avenue, on land recently transferred to the Government, should also be replaced by a new and more sightly structure. The increased income from rental of these two concessions will well repay for the construction of buildings adequate for the service of the constantly increasing number of visitors.

Bird house.—The valuable collection of rare and interesting birds now the property of the Government remains poorly housed for exhibition purposes. Because of the great interest taken in this divi-

sion of the collection and the numbers of beautiful and curious birds from all parts of the world that are presented to the park, the collection is constantly growing. The old bird house was built as a temporary structure many years ago and, in addition to being in a bad condition, is entirely too small either to accommodate the crowds of interested visitors or to show to advantage the birds. Many rare specimens, as a matter of fact, can not regularly be placed on exhibition because of lack of room. It is greatly to be hoped that a new bird house may be provided for in the near future.

Funds for purchase of animals.—The park has never had sufficient funds for the purchase of animals. Rare specimens are from time to time offered for sale that would fill distinct gaps in the collection, but because of lack of funds for their purchase these are frequently lost to the park. Two conspicuous forms of mammal life—the Indian rhinoceros and giraffe—may be mentioned as examples. Opportunities to purchase good specimens of these spectacular species do not often come, but because of lack of money for their purchase the park has had to decline the few offered in recent years. In order that special opportunities may be taken advantage of promptly, there should be available from year to year a reasonable sum for the purchase and transportation of animals.

Respectfully submitted.

N. HOLLISTER, *Superintendent.*

Dr. CHARLES D. WALCOTT,
Secretary, Smithsonian Institution.

APPENDIX 7

REPORT ON THE ASTROPHYSICAL OBSERVATORY

SIR: The Astrophysical Observatory was conducted under the following passage of the independent offices appropriation act approved June 12, 1922:

Astrophysical Observatory: For maintenance of the Astrophysical Observatory, under the direction of the Smithsonian Institution, including assistants, purchase of necessary books and periodicals, apparatus, making necessary observations in high altitudes, repairs and alterations of buildings, and miscellaneous expenses, \$15,500.

The observatory occupies a number of frame structures within an inclosure of about 16,000 square feet south of the Smithsonian administration building at Washington, and also a cement observing station and frame cottage for observers on a plot of 10,000 square feet leased from the Carnegie Solar Observatory, on Mount Wilson, Calif.

A new solar observing station on Mount Harqua Hala, Ariz., was erected in July, 1920, at the expense of funds donated for the purpose by Mr. John A. Roebling, of Bernardsville, N. J., and this station has been occupied as a solar radiation observing station by the Astrophysical Observatory since October, 1920.

The present value of the buildings and equipment for the Astrophysical Observatory, owned by the Government, is estimated at \$50,000. This estimate contemplates the cost required to replace the outfit for the purposes of the investigation.

Work at Washington.—No observations were attempted at Washington. Mr. Fowle, Mrs. Bond, and the director, as much of his time as possible, were engaged in computations necessary (1) to the search for systematic errors in the work of Mount Harqua Hala, Ariz., and the application of carefully determined corrections thereto; (2) to the publication of a comparison of two years of observations at Mount Harqua Hala, Ariz., and Mount Montezuma, Chile (see *Monthly Weather Review*, February, 1923); (3) to the preparation of a new set of curves for use from January 1, 1923, in the short method of solar constant determination at Montezuma, Chile; (4) to the search for systematic errors and the application of carefully determined corrections to Montezuma results on the new basis; (5) to

the reduction of observations made at Mount Wilson in 1922 on the form of the solar spectrum energy curve and on the spectrum energy curves of ten of the brighter stars.

It was apparent from the comparison just referred to between the results of the two field stations that they were in close accord on the sun's variation. But the Chile station was employing in its reductions the results of work prior to 1913 on the distribution of radiation in the solar energy spectrum; while the Arizona station was employing results of 1920. Moreover, the pyranometer in use in Chile was of an old type unsuitable to the work. Furthermore, the sharpness of definition of the spectrum employed at Mount Harqua Hala was inferior to that employed at Montezuma. It seemed probable that to remedy these defects and put the two stations on equality in all respects would lead to even closer harmony in their results, although it meant a revision of the whole scheme of reductions at both stations, with a redetermination of the systematic errors at each. This is very important, for the solar variations rarely exceed 5 per cent, and are mainly less than 2 per cent. It taxes the best observing to reveal them. These were the circumstances which led to the large computing program stated in the preceding paragraph. It has resulted in putting the two stations on equal footing in every possible way. They are now capable of turning out jointly the best results on the solar variation that our experience can suggest a means to attain.

The instrument maker, Mr. Kramer, has been on detached service for almost the entire year, engaged in the preparation, according to plans of the director, of two solar radiation outfits ordered, respectively, by a committee of interested gentlemen in Australia and by the Government of Argentina. The Australian outfit was finished and sent forward in June, 1923. The Argentine outfit will go forward about December, 1923.

Field work at Mount Wilson.—Messrs. Abbot and Aldrich observed on Mount Wilson in the months of July, August, and the fore part of September, 1922. They redetermined the form of the solar spectrum energy curve. For this investigation they employed several different prisms, including two of rock salt. Their object in this course was to vary the procedure, as far as possible, so as to get several independent checks on the results. Upon reduction, all of the results of 1922 came into good accord with one another, and confirmed the work of 1920 very satisfactorily. It now appears that a large part of the earlier work, on which results published in Volumes III and IV of the *Annals* were based, was injured in accuracy by the employment of a quartz prism of inferior transparency. If this quartz prism work is rejected, the remaining early work is

in fair accord with that of 1920 and 1922. The new results, therefore, now are accepted, and were published immediately after their completion. (Smithsonian Miscellaneous Collections, Vol. 74, No. 7, 1923.)

In the course of this solar energy spectrum work, the observers made solar energy curves with rock-salt prisms at different hours of the day, extending as far down the spectrum as to wave-length 14 microns. As yet these observations are not reduced.

A long and difficult task was undertaken in the observation of the prismatic energy spectra of 10 of the brighter stars in the focus of the 100-inch reflector on Mount Wilson. After much discouragement in preparation of apparatus and preliminary trials, successful results were obtained on three nights. The apparatus included a special bolometer and a special galvanometer. Changes of temperature of about one one-hundred-millionth of a degree Centigrade were observable, and electric currents of about 10^{-12} amperes were read with the galvanometer of 10 ohms resistance. So sensitive was the device that it was affected to an almost incredible extent by electromagnetic induction. It even appeared that the operation of electric power in Pasadena and Los Angeles was effective to cause disturbance through the transmission lines up the mountain though cut off at the power house a thousand feet away from the telescope. Accordingly, best observations were made after 2 o'clock in the morning. The results are given in the paper just cited.

Field work in Arizona and Chile.—The Mount Harqua Hala station observed solar variation throughout the year under the efficient direction of Mr. A. F. Moore, assisted until April, 1923, by Mr. F. A. Greeley. Mr. P. E. Greeley, who had been at Montezuma, exchanged places with his brother and reported at Harqua Hala about June 8, 1923.

Mr. L. B. Aldrich assumed the directorship at Montezuma about December 20, 1922, succeeding Mr. L. H. Abbot. At both stations the results of 1923 have been very numerous. They had not yet been critically compared at the close of the period covered by this report.

RESULTS OF THE WORK ON SOLAR RADIATION

As long ago as 1903, we found in the observations then being conducted in Washington some indication of a variation of the sun's output of radiation. These indications were pursued for several years at Mount Wilson and Mount Whitney, and became so strong that, in 1911 and 1912, expeditions were maintained in Algeria, coincident with one at Mount Wilson, to test whether the supposed solar variations were really of local character. The results seemed

confirmatory of real solar changes. The work went on in summer months at Mount Wilson, with gradual improvements up to 1920.

In the meantime Mr. H. H. Clayton, forecaster of the meteorological service of Argentina, had communicated evidence, at first by letter and later in two Smithsonian publications (*Effect of Short Period Variations of Solar Radiation on the Earth's Atmosphere*, Smithsonian Miscellaneous Collections, Vol. 68, No. 3, 1917; and *Variation in Solar Radiation and the Weather*, Smithsonian Miscellaneous Collections, Vol. 71, No. 3, 1920), showing dependence of the weather of various parts of the world on fluctuations of solar radiation. These indications he has now amplified and recently elaborately published (H. H. Clayton, "World Weather," Macmillan Co., New York, 1923). But even at the beginning, to one trained by the late Secretary S. P. Langley to hope that some time some connection would appear between solar and terrestrial changes, Mr. Clayton's work was very interesting.

At the writer's suggestion, Secretary Walcott approved the expenditure of accrued interest from the Hodgkins Fund to undertake all-year-round observations of solar variation in a cloudless climate. The Great War hindered the expedition, but it went forward in 1918 to Calama, Chile, a station chosen on the advice and extensive manuscript data furnished by Dr. Walter Knoche, formerly in charge of the weather service of Chile.

By that time Mr. Clayton's researches had led him to believe that actual forecasts might advantageously be based on solar radiation work. Accordingly, soon after the establishment of the Chile station, arrangements were made to telegraph its results to Buenos Aires, and a system of forecasting based thereon has actually been in use in Argentina for several years. Some of its results are quoted in the book of Mr. Clayton, just cited.

The work almost immediately attracted the favorable attention of Mr. John A. Roebling. By his advice and financial assistance, the Mount Wilson work was transferred to a more cloudless locality for all-year-round observing at Mount Harqua Hala, Ariz., and also the Calama work was transferred to a higher station, Montezuma, outside the dust and smoke of Calama and Chuquicamata, which had been serious inconveniences.

During these many years we had plodded on in hope of a satisfying fruition of our labors. Many signs there were that the solar radiation varies sufficiently to be of importance in terrestrial concerns. But they were of the nature of incompletely verified evidences of various sorts, all pointing the same way, but none in itself conclusive. With the continuous all-year-round occupation of the two first-rate stations, made possible by Mr. Roebling's generosity,

the matter could be put, for the first time, to a rigorous test. And now we have made this test. It is conclusive and proves the substantial character of solar variation. Hereafter we walk by sight, where hitherto we walked by faith.

In the publication cited (*Monthly Weather Review*, February, 1923) we show that in over 100 days, when results were obtained at both Arizona and Chile, the average deviation of one station from the other is 0.68 per cent, thus indicating a probable error of one day's observation at one station of 0.41 per cent. The average deviation for two years of monthly mean values between the two stations is 0.3 per cent, and this small value would doubtless be considerably smaller if the individual days of the several months had always been coincident. Although in opposite hemispheres, where winter at one station falls in summer at the other station, there is no evidence of seasonal divergence between the two stations. They unite in showing solar variation. Indeed the march of the monthly mean values from November, 1921, to September, 1922, in which they agree closely, gives the most conspicuous instance of long-continued solar change in a given direction which we have ever noted. The reader may compare it with the four years of monthly means curve given at the top of the illustration.

In short, there can not be, we think, any longer a reasonable question that the sun varies, or that our observations can reveal these variations satisfactorily. It is now a question for meteorologists whether these variations are of importance in weather forecasting. As we report these satisfying conclusions, it ought to be reported at the same time that the financial support furnished the Astrophysical Observatory by the Government would not have sufficed to obtain these results without the aid of the Hodgkins fund of the Smithsonian Institution, and the generous financial support and wise counsel of Mr. John A. Roebling.

Although done a few days after the close of the period covered by this report, it will be fitting in this connection to mention some preliminary observations on changes of the appearance of the sun accompanying changes in its output of radiation. Being at Pasadena in July, 1923, the director availed himself of permission given by Director Adams to examine two years of record prints from direct photographs and hydrogen ($H\alpha$) spectroheliograms of the sun made at the Mount Wilson Solar Observatory. Four general rules or principles seemed to be well established by the comparisons made.

1. When increased sun-spot activity appears, either by new spot groups forming on the visible solar disk, by the growth of spots already present, or by the coming on of a new group due to the solar rotation, then on that very day the solar constant value increases.

2. When a sun-spot group is carried by the solar rotation across the central diameter of the visible disk, then the solar constant value declines, and usually has a minimum on the day following such central transit.

3. When many spot groups, faculae, or long strings of dark hydrogen flocculi indicate that great solar activity is prevailing, the solar constant is high.

4. When a long quiescent period occurs in solar activity, the solar constant values steadily decline.

These rules connecting the solar radiation with the sun's visible appearance seem to hold some promise of quantitative development. Possibly there may be found some formula for computing solar constant values by the aid of direct solar photographs and hydrogen and calcium spectroheliograms, which may enable the solar radiation values to be expressed with fair approximation for the past quarter of a century. If so, it will be of great advantage.

PERSONNEL

In addition to the changes of personnel above mentioned, Mr. William H. Hoover was temporarily engaged as assistant beginning March 12, 1923. He is in training to be director of the proposed solar radiation observatory of the Argentine Government at La Quiaca, Argentina. Mr. Hoover spent some time in Washington and some upon Mount Harqua Hala, Ariz. Mrs. Arline Leary served as temporary computer, beginning April 16, 1923. Both of these assistants were paid from funds given for the purpose by Mr. John A. Roebling.

SUMMARY

A comparison of two years of results on the variation of solar radiation observed at Mount Harqua Hala, Ariz., and Montezuma, Chile, shows close accord between the stations and agreement between them in showing forth solar changes of both long and short interval types. Monthly mean values of both stations indicate a long continued decline of the output of solar radiation beginning in November, 1921, and continuing at least until September, 1922. This is in some respects the most remarkable solar change on record. Great improvements have been made at both stations, and their observations have been put as far as possible on exactly equal footing. It is believed that beginning January 1, 1924, there will be still closer accord in their results. Definite correspondences have been observed between the variation of the sun's radiation and the variation of the most marked of its visible features. Several new determinations of the form of the sun's energy spectrum distribution

curve confirm the similar work of 1920, and lead to a revision of the results of earlier work published in Volumes III and IV of the Observatory Annals. Energy spectra of 10 of the brighter stars were observed at the focus of the 100-inch telescope on Mount Wilson by means of a special spectrobolometric apparatus. Temperature differences of approximately one one-hundred-millionth of a degree centigrade were measured in this investigation. Solar radiation outfits have been prepared for Australia and Argentina, to be installed in the year 1923.

Respectfully submitted.

C. G. ABBOT, *Director.*

Dr. CHARLES D. WALCOTT,
Secretary, Smithsonian Institution.

APPENDIX 8

REPORT ON THE INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE

SIR: I have the honor to submit the following report on the operations of the United States Regional Bureau of the International Catalogue of Scientific Literature for the fiscal year ending June 30, 1923.

As the success of this international enterprise, in common with all undertakings dependent on international cooperation, is necessarily controlled by world politics, it has been the hope of all interested in the International Catalogue that each year conditions would develop which would make reorganization possible and justify resumption of publication. As international affairs, both political and financial, are apparently still far removed from normalcy, the affairs of the catalogue are practically in the same condition as they were in 1922. As was noted in the last annual report, the Smithsonian Institution submitted a statement of its position to an international convention held in Brussels in July, 1922, to consider the affairs of the catalogue. This statement carried with it a suggestion whose object was to keep the international organization in existence, it being generally conceded that should the countries who are now and have been for the past 22 years officially cooperating in the support of the enterprise be for any reason disunited it would be practically impossible to ever regain their interest and support. Though these suggestions were printed in the last report of this bureau, they are in part reprinted here, as on them were based the resolutions to continue the regional bureaus until reorganization could be accomplished:

It is the belief of the Smithsonian Institution

1. That a classified subject and author index to the literature of science is needed.
2. That no better means exists of attaining the end sought than by carrying out the original plan of the International Catalogue based on international cooperation, guided by uniform rules and schedules modified to meet changes in the several sciences, and, when possible, broadened in scope to include the allied technical branches of these sciences.
3. That every effort should be made to cooperate with all similar enterprises, including abstracting agencies, existing or projected, not only to prevent duplication of labor, but also to better serve the demands of those in need of bibliographic aid.

4. That on account of abnormal conditions still controlling publishing costs and monetary exchange, it is probable that actual publication can not be at present resumed unless financial aid is had from some source outside the present organization; however, it is believed,

5. That the international organization should be kept in being through mutual agreement to continue the work of the regional bureaus until such time as it may be economically possible to resume publication. When that time arrives the stock of complete sets already published should be advertised for sale at a price within the reach of the smaller libraries and institutions, many of whom, although desiring this unique reference work, were prevented from subscribing on account of the high original cost.

Were the price reduced even to one-fourth of the original, stock in hand at that figure represents a sufficient sum to meet all outstanding obligations and leave a surplus for working capital.

This statement was read at the opening meeting of the convention and after a short discussion the following resolutions were adopted:

That the convention is of opinion that the international organization should be kept in being through mutual agreement to continue as far as possible the work of the regional bureaus until such time as it may be economically possible to resume publication.

That it be referred to the executive committee to consider and after full consultation with interested bodies to make proposals as to the form of future publication and to report with some definite scheme to a meeting of the international council to be summoned as soon as it appears possible that the publication can be resumed.

The executive committee referred to consists of one representative from each of the following-named countries; England, France, Italy, Japan, Holland, Denmark, and the United States.

At this convention Prof. Henry E. Armstrong, chairman of the executive committee, who is the only one of the founders of the catalogue remaining in the organization, submitted a report from which the following items have been copied:

At the outset there was great enthusiasm for the work among those who were its promoters in the different countries and great care was taken in the preparation of the scheme; the organization that has been developed, in consequence, has worked with remarkable smoothness. Bureaus have been established in 32 countries, and the relations between these and the central office in London have always been of the most harmonious character possible.

Most convincing proof has been obtained that international cooperation to such an end is not merely possible but may be made most effective. That all that was aimed at has been accomplished need not be contended; but the obvious shortcomings of the catalogue have been almost entirely due to lack of funds. To have established a system so widespread in its operations is no small achievement in itself.

I am profoundly convinced that the principles underlying the preparation of the catalogue are sound and that an international system of cataloguing scientific literature is proved to be feasible and that its advantages are incontestable.

It is the first work of the kind to be carried out in such detail and over so long a period—more than 20 years. To abandon the enterprise after so satisfactory a foundation has been laid would be to sacrifice an unique experience gained at the expense of great labor.

From the foregoing facts and opinions and from the experience of all who have occasion to use bibliographical aids, in matters relating to science and all its branches, it is apparent—

1. That there is a need for recording for the purpose of present and future reference the published results of scientific achievements.

2. That such a record to be comprehensive and complete must be international in its scope and therefore must necessarily be prepared through international cooperation.

3. That excepting for the organization known as the International Catalogue of Scientific Literature, no such agency exists.

4. That, though not claiming perfection, the International Catalogue up to the beginning of the late war was and had been for some 14 years answering the demands and requirements of an international authors' list and classified subject index to the world's literature of science.

5. That the principal defects of the International Catalogue were lack of capital; lack of complete cooperation with enterprises similar in nature though more limited in scope.

All of these defects had been recognized and their correction provided for by authority vested in the executive committee, whose plans were frustrated by the beginning of war and consequent financial collapse. It is believed and maintained by the advocates of the International Catalogue that the foundation as it at present exists, in spite of its financial difficulties, is the best and only one in existence on which to build a new and more far-reaching organization, trespassing on no occupied fields, though cooperating for the common good with all enterprises having the same or similar objects in view.

While many projects have been proposed and are now being advocated, none either in plan or scope compare with the International Catalogue and none have the international recognition and official support necessary for success. The capital needed to refinance the enterprise is so small in comparison with the results to be attained that it would be strange indeed if in this day of large ideas and large financial outlays this most promising bond between and aid for the thinkers and workers of all nations should be allowed to remain so crippled that its wealth of information must continue to be inaccessible because unpublished.

Respectfully submitted.

LEONARD C. GUNNELL,
Assistant in Charge.

Dr. CHARLES D. WALCOTT,
Secretary, Smithsonian Institution.

APPENDIX 9

REPORT ON THE LIBRARY

SIR: I have the honor to submit the following report on the activities of the library of the Smithsonian Institution for the fiscal year ended June 30, 1923.

Much has been accomplished, it is felt, toward better library service. Principal original articles, appearing in scientific and technical periodicals received for the Smithsonian deposit, have been brought to the attention of members of the staff, through the continued preparation of a daily list, circulated among heads of scientific bureaus under the Smithsonian Institution. Books in the employees' library have been rendered more accessible by their transfer to the present quarters. Better protection has been provided for the older accession books and other records by their removal to darker and less frequented quarters, and congestion has thus been relieved in the receiving room and in the filing cases. The number of publications loaned during the year reached a total of 12,076, and fully as many were consulted without being taken out.

Many rare volumes that otherwise would have required purchase at great expense have been received in exchange or by gift. Back numbers of publications required to complete sets have been requested in exchange from societies and organizations abroad, and many have generously responded during the year by presenting valuable material, hitherto not available in American libraries. Special attention has been given to the transmittal of Smithsonian publications in exchange.

FOREIGN PERIODICALS

A classified list has been prepared during the year of foreign periodicals, exclusive of annuals and irregular serials, and the following table of subjects and languages is submitted:

Subject	English	French	Germanic	Italian	Spanish
Aeronautics.....	4	7	4	1	3
Agriculture.....	19	19	4	6	11
Anthropology.....	17	9	6	2	1
Archeology.....	10	15	1	3	3
Art.....	5	3	-----	3	1
Astronomy.....	10	4	4	1	4
Bibliography.....	7	8	4	2	14
Biology—general.....	13	5	1	1	2
Botany.....	9	9	6	3	1
Chemistry.....	7	7	7	-----	-----
Economics.....	10	7	4	1	5
Education.....	8	5	2	-----	17
Engineering.....	38	11	6	3	11
Entomology.....	5	4	7	1	1
Geography.....	18	15	9	2	2
Geology.....	10	13	3	2	4
History.....	6	5	8	5	5
Ichthyology.....	3	1	3	3	-----
Mathematics.....	3	3	3	3	-----
Medical sciences.....	8	15	8	4	10
Meteorology.....	11	4	4	4	3
Navigation.....	4	1	2	1	2
Ornithology.....	4	4	6	1	1
Philology.....	1	5	7	2	1
Physics.....	3	3	12	1	1
Science—general.....	25	27	15	13	16
Zoology—general.....	5	8	7	1	-----
Total.....	263	217	143	69	119

BIBLIOGRAPHIC RESEARCHES

The third volume of the "Bibliography of Aeronautics," covering the years 1917 to 1919, inclusive, compiled by the assistant librarian of the Smithsonian Institution, Paul Brockett, was issued during the year by the National Advisory Committee for Aeronautics. The first volume of this bibliography was issued in 1910 as volume 55 of the Smithsonian Miscellaneous Collections.

Efforts have been made for a number of years to compile a catalogue of the Watts de Peyster collection, Napoleon Bonaparte, and a bibliography of scientific and technical periodicals, but up to the past few years it has not been possible to devote much time to these projects. During the past year, however, Mr. Condit has been able to bring together a catalogue of the rarer historical works in the Watts de Peyster collection, and to prepare a classified list of current foreign periodicals received for the library. The latter work should not be confused with the larger plan, under way for many years, for the compilation of a list of publications of learned societies of the world in libraries throughout the United States. The completion of this project does not seem possible without the expenditure of a large sum of money, which is not at present available.

In the following reports of libraries administered under the Smithsonian Institution, a decrease will be noted in accessions, the natural consequence of the decline in publication abroad and the fact that war accumulations were taken care of last year.

SMITHSONIAN MAIN LIBRARY

The additions to the main library, numbering 5,719, have been transmitted to the Smithsonian deposit in the Library of Congress, where they are made available to the public. Documents of foreign Governments, received in exchange for Smithsonian publications, have been transmitted in accordance with the established practice, without stamping or recording. The number of publications accessioned has now reached 893,307.

Theses were received from universities and institutes of technology abroad located at the following places: Amsterdam, Basel, Berlin, Bern, Bonn, Breslau, Clermont, Copenhagen, Delft, Dresden, Freiburg, Ghent, Giessen, Halle, Helsingfors, Karlsruhe, Kiel, Königsberg, Leipzig, Lund, Rostock, Tokyo, Tübingen, Utrecht, Zürich.

A number of universities have temporarily discontinued the practice of sending the complete thesis, owing to the increased cost of printing, and are now submitting them in abstract only.

Missing parts of incomplete sets were requested in exchange, as in previous years, with an increased percentage secured, although there was a decline both in wants requested and in wants secured. Of 2,174 publications requested, 921 were secured, a percentage of 43.2 as against 39.1 for last year.

SMITHSONIAN OFFICE LIBRARY

The number of publications loaned from the office library was 2,756. The accessions numbered 378, of which 347 were volumes and the remainder parts and pamphlets. Attention should be called to the fact that no binding has been done for the office library during the last six years, owing to lack of funds.

The progress of the cataloguing in the general library catalogue of the Smithsonian Institution, kept in the office library, is shown by the following statistics:

	1922-1923	1921-1922
Volumes catalogued.....	6,341	6,502
Volumes recatalogued.....	109	55
Charts catalogued.....	198	160
Typed cards.....	3,870	4,243
Library of Congress cards filed.....	858	592
New titles added to author catalogue.....	2,299	1,614

Of the special collections in the office library, mention has been previously made of activities in connection with the aeronautical collection, the Watts de Peyster collection, and the employees' library.

Mention should also be made of the collection deposited by Mrs. Charles D. Walcott, who has kindly extended the period of deposit. It is frequently consulted by employees of the Smithsonian Institution.

UNITED STATES NATIONAL MUSEUM

The widespread interest of members of the staff and friends of the museum is shown by the material donated during the year. Among the donors are Messrs. H. E. Boving, A. H. Clark, F. W. Clarke, W. H. Dall, Whitman Cross, C. G. Gilbert, O. P. Hay, A. D. Hopkins, Aleš Hrdlička, Emmanuel de Margerie, W. R. Maxon, W. de C. Ravenel, C. W. Richmond, S. A. Rohwer, W. Schaus, and Charles D. Walcott. The gifts of Doctor Dall to the sectional library of mollusks numbered 168 titles.

Valuable material has continued to come in exchange from museums, research organizations, and scientific societies at home and abroad.

The receipts of the year numbered 1,489 volumes and 2,796 pamphlets, bringing the total of books and other material in the library up to 160,560. Of these there are 62,170 accessioned volumes. New entry cards were made for 239 periodicals, and 13,314 parts were entered.

Much of the library's reference service is rendered through the sectional libraries, under the immediate custody of members of the scientific and administrative staff, located as follows:

NATURAL HISTORY BUILDING

American archeology.	Mollusks.
Anthropology.	Old World archeology.
Birds.	Paleobotany.
Fishes.	Physical anthropology.
Geology.	Property clerk's office.
Invertebrate paleontology.	Reptiles and batrachians.
Mammals.	Superintendent's office.
Marine invertebrates.	Vertebrate paleontology.
Minerals.	

ARTS AND INDUSTRIES BUILDING

Administration.	Medicine.
Administrative assistant's office.	Mineral technology.
Foods.	Photography.
History.	Textiles.
Mechanical technology.	Wood technology.

SMITHSONIAN BUILDING AND ANNEX

Botany.	Taxidermy.
Editor's office.	War library.
Graphic arts.	

It will be seen that the use of the library can not be estimated upon the basis of its loans alone. Many volumes are consulted in the general library, the technological library, and the various sectional libraries without being taken out. References are frequently requested over the telephone by members of the staff of the Museum and other Government bureaus, and every effort is made to comply with these requests. Of the 9,220 loans made during the year, 5,191 were to the sectional libraries and 1,929 were borrowed from other libraries.

The subject catalogue of the library has been increased by 4,400 cards. The arrangement of accumulated cards from the Concilium Bibliographicum, received since the close of the war, has been progressing and is well under way.

ASTROPHYSICAL OBSERVATORY LIBRARY

The requirements of the staff of the Astrophysical Observatory, both in Washington and at the various stations, in the way of reference service, are met through the Astrophysical Observatory Library. Loans are made through the Smithsonian Office Library. There were added during the year 113 volumes, 27 parts of volumes, and 54 pamphlets.

BUREAU OF AMERICAN ETHNOLOGY LIBRARY

The activities of the Bureau of American Ethnology Library are covered in the report of the chief of that bureau. The library is administered under his immediate direction.

NATIONAL ZOOLOGICAL PARK LIBRARY

The library of the National Zoological Park, located three miles distant from the Smithsonian building, contains supplemental material of importance in the fields of zoology and park administration. The increase for the year, as shown by accessions, was six volumes and four parts.

NATIONAL GALLERY OF ART LIBRARY

The National Gallery of Art Library is rapidly growing. Since the gallery has begun the issuance of a separate series of publications there has been a noteworthy increase in the material that has been received in exchange. There were accessioned 128 volumes and 213 periodicals. Periodical parts numbered 740. The gift of the year most worthy of mention is the large, handsomely illustrated volume of paintings in the Bachstitz Gallery at The Hague.

FREER GALLERY OF ART LIBRARY

In connection with the art collections in the Freer building, a large library was brought together by Mr. Freer. A catalogue of the works contained in it has not been incorporated in the general library of the Institution. There have been, however, 137 accessions in the library, and 10 of these were added during the year. Many other volumes belonging to the Smithsonian Institution have been deposited in that building, to be retained indefinitely, most of these being reference works and volumes relating to Oriental art.

SUMMARY OF RECEIPTS AND ACCESSIONS

The number of pieces of mail received during the year was 25,553, of which 6,272 publications were Government documents, and were sent to the Library of Congress, in accordance with the established practice. Additions to the library, as shown by the accession records, are given below.

Library	Volumes	Other publications	Total
Astrophysical Observatory.....	113	81	194
Freer Gallery of Art.....	10	1	11
National Gallery of Art.....	128	213	341
National Zoological Park.....	6	4	10
Smithsonian deposit.....	4,461	1,258	5,719
Smithsonian office.....	347	31	378
United States National Museum.....	1,489	2,796	4,285
Total.....	6,554	4,384	10,938

Respectfully submitted.

PAUL BROCKETT,
Assistant Librarian,

Dr. CHARLES D. WALCOTT,
Secretary, Smithsonian Institution.

APPENDIX 10

REPORT ON THE PUBLICATIONS

SIR: I have the honor to submit the following report on the publications of the Smithsonian Institution and its branches during the year ending June 30, 1923:

The Institution proper published during the year 9 papers in the series of Miscellaneous Collections, 1 annual report and pamphlet copies of 30 articles in the general appendix to this report, and 3 special publications. The Bureau of American Ethnology published 2 bulletins and 2 annual reports. The United States National Museum issued 1 annual report, 2 volumes of proceedings, 37 separates from the proceedings, 6 bulletins, 2 parts of bulletins, and 4 parts of volumes in the series of Contributions from the United States National Herbarium. The National Gallery of Art issued 1 volume in the series of Catalogues of Collections.

Of these publications there were distributed during the year 139,666 copies, which includes 130 volumes and separates of the Smithsonian Contributions to Knowledge, 18,801 volumes and separates of the Smithsonian Miscellaneous Collections, 25,229 volumes and separates of the Smithsonian annual reports, 3,016 Smithsonian special publications, 72,529 volumes and separates of the various series of National Museum publications, 17,694 publications of the Bureau of American Ethnology, 816 publications of the National Gallery of Art, 1,309 volumes of the Annals of the Astrophysical Observatory, 31 reports on the Harriman Alaska expedition, 74 reports of the American Historical Association, and 37 publications presented to but not issued directly by the Smithsonian Institution or its branches.

SMITHSONIAN MISCELLANEOUS COLLECTIONS

Of the Smithsonian Miscellaneous Collections, volume 56, 1 paper was issued; volume 67, 1 paper; volume 74, 6 papers; volume 76, 1 paper; in all, 9 papers, as follows:

VOLUME 56

No. 19. The Silver Disk Pyrhellometer (Reprint, revised). By C. G. Abbot. July 10, 1922. 10 pp., 1 pl. (Publ. 2008.)

VOLUME 67

No. 8. Cambrian Geology and Paleontology. IV, No. 8. Nomenclature of Some Post Cambrian and Cambrian Cordilleran Formations (2). By Charles D. Walcott. March 5, 1923. pp. 457-476. (Publ. 2673.)

VOLUME 74

No. 2. New Timaline Birds from the East Indies. By Harry C. Oberholser. September 27, 1922. 13 pp. (Publ. 2674.)

No. 3. Remains of Mammals from Caves in the Republic of Haiti. By Gerrit S. Miller, jr. October 16, 1922. 8 pp. (Publ. 2707.)

No. 4. Remains of Birds from Caves in the Republic of Haiti. By Alexander Wetmore. October 17, 1922. 4 pp. (Publ. 2708.)

No. 5. Explorations and Field-work of the Smithsonian Institution in 1922. May 4, 1923. 153 pp., 145 figs. (Publ. 2711.)

No. 6. Designs on Prehistoric Pottery from the Mimbres Valley, New Mexico. By J. Walter Fewkes. May 29, 1923. 47 pp., 140 figs. (Publ. 2713.)

No. 7. The Distribution of Energy in the Spectra of the Sun and Stars. By C. G. Abbot, F. E. Fowle, and L. B. Aldrich. June 4, 1923. 30 pp. (Publ. 2714.)

VOLUME 76

No. 1. Some Practical Aspects of Fuel Economy. By Carl W. Mitman. June 2, 1923. 19 pp. (Publ. 2715.)

In press at close of year

VOLUME 76

No. 2. History of Electric Light. By Henry Schroeder. (Publ. 2717.)

No. 3. On the Fossil Crinoid Family Catillocrinidae. By Frank Springer. (Publ. 2718.)

No. 4. Report on Cooperative Educational and Research Work Carried on by the Smithsonian Institution and its Branches. (Publ. 2719.)

No. 5. The Telescoping of the Cetacean Skull. By Gerrit S. Miller, jr. (Publ. 2720.)

No. 6. Descriptions of New East Indian Birds of the Families Turdidae, Sylviidae, Pycnonotidae, and Muscicapidae. By Harry C. Oberholser. (Publ. 2721.)

No. 7. Description of an Apparently New Toothed Cetacean from South Carolina. By Remington Kellogg. (Publ. 2723.)

SMITHSONIAN ANNUAL REPORTS

REPORT FOR 1921

The Annual Report of the Board of Regents for 1921 was received from the Public Printer in June, 1923.

Annual Report of the Board of Regents of the Smithsonian Institution, showing operations, expenditures, and condition of the Institution for the year ending June 30, 1921. xi+638 pp., 113 pls. (Publ. 2675.)

The general appendix to this report contains the following papers:

The daily influence of astronomy, by W. W. Campbell.

Cosmogony and stellar evolution, by J. H. Jeans.

The diameters of the stars, by A. Danjon.

Isotopes and atomic weights, by F. W. Aston.

Modifying our ideas of nature: The Einstein theory of relativity, by Henry Norris Russell.

The alkali problem in irrigation, by Carl S. Scofield.

An outline of geophysical-chemical problems, by Robert B. Sosman.

The yielding of the earth's crust, by William Bowie.

The age of earth, by the Right Hon. Lord Rayleigh, W. J. Sollas, J. W. Gregory, and Harold Jeffreys.

The department of geology of the U. S. National Museum, by George P. Merrill.

Some observations on the natural history of Costa Rica, by Robert Ridgway.

The historic development of the evolutionary idea, by Branislav Petronievs.

The heredity of acquired characters, by L. Cuénot.

Breeding habits, development, and birth of the opossum, by Carl Hartman.

Some preliminary remarks on the velocity of migratory flight among birds, with special reference to the Palaearctic region, by R. Meinertzhagen.

A botanical reconnaissance in southeastern Asia, by A. S. Hitchcock.

Ant acacias and acacia ants of Mexico and Central America, by W. E. Safford.

The fall webworm, by R. E. Snodgrass.

Collecting insects on Mount Rainier, by A. L. Melander.

The science of man: Its needs and prospects, by Karl Pearson.

Pigmentation in the old Americans, with notes on graying and loss of hair, by Aleš Hrdlička.

Ancestor worship of the Hopi Indians, by J. Walter Fewkes.

The Indian in literature, by Herman F. C. Ten Kate.

Leopard men in the Naga Hills, by J. H. Hutton.

A new era in Palestine exploration, by Elihu Grant.

The alimentary education of children, by Marcel Labbé.

A fifty-year sketch history of medical entomology, by L. O. Howard.

Laid and wove, by Dard Hunter.

Lead, by Carl W. Mitman.

William Crawford Gorgas, by Robert E. Noble.

REPORT FOR 1922

The report of the executive committee and proceedings of the Board of Regents of the Institution, and the report of the secretary, both forming part of the annual report of the Board of Regents to Congress, were issued in pamphlet form in December, 1922.

Report of the executive committee and proceedings of the Board of Regents of the Smithsonian Institution for the year ending June 30, 1922. 10 pp. (Publ. 2710.)

Report of the Secretary of the Smithsonian Institution for the year ending June 30, 1922. 125 pp. (Publ. 2709.)

The general appendix to this report, the manuscript of which went to the Government Printing Office a few days after the close of the fiscal year, contains the following articles:

Who will promote science? by C. G. Abbot.

Recent discoveries and theories relating to the structure of matter, by Karl Taylor Compton.

The architecture of atoms and a universe built of atoms, by C. G. Abbot.

Aeronautic research, by Joseph S. Ames.

Photosynthesis and the possible use of solar energy, by H. A. Spoehr.

Fogs and clouds, by W. J. Humphreys.

Some aspects of the use of the annual rings of trees in climatic study, by Prof. A. E. Douglass.

The age of the earth, by T. C. Chamberlin and others.

How deep is the ocean? by C. G. Abbot.

Two decades of genetic progress, by E. M. East.

Observations on a Montana beaver canal, by S. Stillman Berry.

The Republic of Salvador, by Paul C. Standley.

The tent caterpillar, by R. E. Snodgrass.

The life history and habits of the solitary wasp, *Philanthus gibbosus*, by Edward G. Reinhard.

The use of idols in Hopi worship, by J. Walter Fewkes.

Two Chaco Canyon pit houses, by Neil M. Judd.

Collections of Old World archeology, in the United States National Museum, by I. M. Casanowicz.

The "Shake Religion" of Puget Sound, by T. T. Waterman.

Excavations at Askalon, by Prof. J. Garstang.

National efforts at home making, by F. H. Newell.

Ideals of the telephone service, by John J. Carty.

SPECIAL PUBLICATIONS

The Smithsonian Institution (descriptive pamphlet), 7 pp.

Title page and contents of Volume 62, Smithsonian Miscellaneous Collections. (Publ. 2716.)

Title page and contents of Volume 72, Smithsonian Miscellaneous Collections. (Publ. 2706.)

PUBLICATIONS OF THE UNITED STATES NATIONAL MUSEUM

The publications of the National Museum are: (a) The annual report, (b) the Proceedings of the United States National Museum, and (c) the Bulletin of the United States National Museum, which includes the Contributions from the United States National Herbarium. The editorship of these publications is vested in Dr. Marcus Benjamin.

During the year ending June 30, 1923, the Museum published 1 annual report, 2 volumes of proceedings, 6 complete bulletins, 2 parts of bulletins, 4 parts of volumes in the series Contributions from the United States National Herbarium, and 37 separates from the proceedings.

The issues of the bulletin were as follows:

Bulletin 100, volume 5. Contributions to the biology in the Philippine Archipelago and adjacent regions.—Ophiurans of the Philippine seas and adjacent waters. By Rene Koehler.

Bulletin 120. The opalinid ciliate infusorians. By Maynard M. Metcalf.

Bulletin 121. Life histories of North American petrels and pelicans and their allies—Order Tubinares and order Steganopodes. By Arthur Cleveland Bent.

Bulletin 122. A monograph of the American shipworms. By Paul Bartsch.

Bulletin 123. Revision of the North American moths of the subfamily Eucosminae of the family Olethreutidae. By Carl Heinrich.

Bulletin 124. The type species of the genera of Chalcidoidea or Chalcid-flies.

By A. B. Gahan and Margaret M. Fagan.

Bulletin 126. Life histories of North American wild fowl—Order Anseres (part). By Arthur Cleveland Bent.

Of the separate papers of the Contributions from the United States National Herbarium, the following were issued:

Volume 23, part 2. Trees and Shrubs of Mexico. (Fagaceae-Fabaceae). By Paul C. Standley.

Volume 24, part 2. Studies of tropical American ferns, No. 7. By William R. Maxon.

Volume 24, part 3. Key to the Genus *Diplostephium*, with Descriptions of New Species. By S. F. Blake.

Volume 24, part 4. Native Names and Uses of Some Plants of Eastern Guatemala and Honduras. By S. F. Blake.

Of the separates from the proceedings, 5 were from volume 61, 21 from volume 62, and 11 from volume 63.

PUBLICATIONS OF THE BUREAU OF AMERICAN ETHNOLOGY

The editorial work of the Bureau of American Ethnology is under the direction of Mr. Stanley Searles, editor. During the year there were published two annual reports and two bulletins, as follows:

Thirty-fourth Annual Report. Accompanying papers: A Prehistoric Island Culture Area of America (Fewkes). 281 pp., 120 pls., 69 figs.

Thirty-seventh Annual Report. Accompanying paper: The Winnebago Tribe (Radin). 560 pp., 58 pls., 38 figs.

Bulletin 76. Archeological Investigations (Fowke). 204 pp., 45 pls., 37 figs.

Bulletin 77. Villages of the Algonquian, Siouan, and Caddoan Tribes west of the Mississippi (Bushnell). 211 pp., 55 pls., 12 figs.

There were in press or in preparation at the close of the year 4 annual reports and 5 bulletins, as follows:

Thirty-eighth Annual Report. Accompanying paper: An Introductory Study of the Arts, Crafts, and Customs of the Guiana Indians (Roth).

Thirty-ninth Annual Report. Accompanying paper: The Osage Tribe: The Rite of Vigil (La Flesche).

Fortieth Annual Report. Accompanying papers: The Mythical Origin of the White Buffalo Dance of the Fox Indians; The Autobiography of a Fox Indian Woman; Notes on Fox Mortuary Customs and Beliefs; Notes on the Fox Society known as "Those Who Worship the Little Spotted Buffalo"; The Traditional Origin of the Fox Society known as "The Singing-Around Rite" (Michelson).

Forty-first Annual Report. Accompanying paper: Social Organization and Social Usages of the Indians of the Creek Confederacy (Swanton).

Bulletin 78. Handbook of the Indians of California (Kroeber).

Bulletin 79. Blood Revenge, War, and Victory Feasts among the Jibaro Indians of Eastern Ecuador (Karsten).

Bulletin 80. Mandan and Hidatsa Music (Densmore).

Bulletin 81. Excavations in the Chama Valley, New Mexico (Jeancon).

Bulletin 82. Fewkes and Gordon Groups of Mounds in Middle Tennessee. (Myer).

REPORT OF THE AMERICAN HISTORICAL ASSOCIATION

The annual reports of the American Historical Association are transmitted by the association to the secretary of the Smithsonian Institution, and by him are communicated to Congress under provisions of the act of incorporation of the association.

The annual report for 1919 was still in press at the close of the year, and there were also in press the supplemental volumes entitled "Writings in American History," to the reports for 1919, 1920, and 1921.

REPORT OF THE NATIONAL SOCIETY, DAUGHTERS OF THE AMERICAN REVOLUTION

The manuscript of the Twenty-fifth Annual Report of the National Society, Daughters of the American Revolution was transmitted to Congress according to law on December 28, 1922.

THE SMITHSONIAN ADVISORY COMMITTEE ON PRINTING AND PUBLICATION

The editor has continued to serve as secretary of the Smithsonian advisory committee on printing and publication. To this committee are referred for consideration and recommendation all manuscripts offered for publication by the Smithsonian Institution and its branches, and it also considers routine forms and other matters relating to printing and publication. Seven meetings were held during the year and 104 manuscripts were acted upon.

Respectfully submitted.

W. P. TRUE, *Editor.*

Dr. CHARLES D. WALCOTT,
Secretary, Smithsonian Institution.

REPORT OF THE EXECUTIVE COMMITTEE OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION FOR THE YEAR ENDED JUNE 30, 1923

To the Board of Regents of the Smithsonian Institution:

Your executive committee respectfully submits the following report in relation to the funds, receipts, and disbursements of the Institution and a statement of the appropriations by Congress for the National Museum, the International Exchanges, the Bureau of American Ethnology, the National Zoological Park, the Astrophysical Observatory, the International Catalogue of Scientific Literature, and the National Gallery of Art, for the fiscal year ended June 30, 1923:

SMITHSONIAN INSTITUTION

Condition of the fund July 1, 1923

The sum of \$1,000,000 deposited in the Treasury of the United States under act of Congress is a permanent fund, having been accumulated by the deposit of savings and bequests from time to time. Subsequent bequests and gifts and the income therefrom, when so required, are invested in approved securities. The several specific funds so invested are now constituted as follows and classed as the consolidated fund:

Avery fund	\$27, 689. 80
Virginia Purdy Bacon fund.....	48, 300. 00
Lucy H. Baird fund.....	1, 285. 58
Chamberlain fund	35, 000. 00
Hamilton fund	500. 00
Caroline Henry fund.....	1, 023. 00
Hodgkins general fund.....	37, 275. 00
Bruce Hughes fund.....	11, 194. 76
Morris Loeb fund.....	2, 390. 00
Lucy T. and George W. Poore fund.....	10, 055. 00
Addison T. Reid fund.....	4, 419. 00
Rhees fund.....	238. 00
George K. Sanford fund.....	451. 00
Smithson fund.....	1, 429. 14
Charles D. and Mary Vaux Walcott research fund.....	11, 520. 00
Total consolidated fund	192, 770. 28

A piece of improved real estate, at 140 East Capitol Street, Washington, D. C., forming a part of the original bequest of the late Robert Stanton Avery, has been sold. Payment in part was made in cash and the balance by note.

The total amount of dividends and interest received by the Institution from the Freer estate during the year for all purposes was \$304,436.26. The increase in revenue was partly due to the settlement of the estate by the administrators and also to the fact that Parke, Davis & Co. declared a 100 per cent stock dividend to holders of record December 18, 1922.

The itemized report of the auditor is filed in the office of the secretary.

Detailed survey of financial operations

Ordinary receipts:

Cash balance on hand July 1, 1922	\$6, 364. 15
Income from miscellaneous sources available for general purposes	55, 856. 35
International Exchanges, repayments to the Institution for specific purposes	5, 263. 66
Total resources for ordinary purposes	<u>67, 484. 16</u>

Ordinary expenditures:

Care and repair of buildings	8, 013. 08
Furniture and fixtures	1, 535. 34
General administration	24, 766. 39
Library	3, 197. 67
Publications (comprising preparation, printing, and distribution)	13, 463. 27
Researches and explorations	5, 135. 55
International Exchanges	8, 027. 55
Total ordinary expenditures	<u>64, 138. 85</u>

Advances and repayments for field expenses and other temporary transactions during the year:

Advances	37, 984. 05
Repayments	25, 214. 88
Difference	<u>12, 769. 17</u>

The above difference will be adjusted in due course.

RECEIPTS AND EXPENDITURES FOR SPECIFIC OBJECTS

Receipts:

Avery fund	\$3,919.72
Harriman trust fund	12,500.00
Hodgkins fund	6,000.00
Hamilton fund	175.00
Rhees fund	47.00
Addison T. Reid fund	845.00
Lucy T. and George W. Poore fund	2,210.15
George H. Sanford fund	87.90
Bruce Hughes fund	559.74
Swales fund	400.00
Caroline Henry Fund	51.00
Morris Loeb fund	5,882.50
Dr. W. L. Abbott research fund	4,000.00
John A. Roebling solar research fund	28,288.19
Frances Lea Chamberlain fund	1,750.00
Lucy H. Baird fund	64.28
Virginia Purdy Bacon fund	2,400.00
Charles D. and Mary Vaux Walcott fund	576.00
Total	69,756.48

Expenditures:

John A. Roebling fund, for solar research	15,156.36
Swales fund, for specimens	170.94
Chamberlain fund, for specimens	1,176.03
Hodgkins fund, for solar research	5,333.82
Harriman trust fund, for researches and specimens	10,136.52
Rhees fund, invested	39.00
Avery fund, invested	3,200.00
Addison T. Reid fund, invested	740.00
Lucy T. and George W. Poore fund, invested	1,611.00
Lucy T. and George W. Poore fund, taxes	313.60
George H. Sanford fund, invested	77.00
Bruce Hughes fund, invested	1,300.00
Virginia Purdy Bacon fund, invested	1,400.00
Caroline Henry fund, invested	23.00
Lucy H. Baird fund, invested	25.00
Morris Loeb fund, expended	247.18
Morris Loeb fund, invested	2,390.00
Charles D. and Mary Vaux Walcott fund, expended	576.00
Hamilton fund, expended	375.80
Total	44,291.25

RECEIPTS AND EXPENDITURES PERTAINING TO THE CHARLES L. FREER BEQUEST

Receipts:

Interest, dividends, and miscellaneous receipts, including installments on Great Lakes engineering works, in liquidation-----	\$304, 436. 26
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Expenditures:

Final payment of temporary loan to settle Freer estate-----	173, 640. 99
Purchase of art objects and other miscellaneous expenditures..	45, 704. 84
Building fund-----	32, 100. 17
Total expenditures-----	251, 446. 00

SUMMARY

Receipts:

Ordinary income for general objects, including cash balance at beginning of year-----	\$87, 484. 16
Revenue and principal of funds conveyed for specific purposes, except the Freer bequest-----	69, 756. 48
Freer bequest-----	304, 436. 26
Total -----	441, 676. 90

Expenditures:

General objects of the Institution-----	64, 138. 85
Expenditures for specific purposes, except the Freer bequest--	44, 291. 25
Advances for field expenses-----	12, 769. 17
Freer bequest-----	251, 446. 00
Cash deposited on time at 3 per cent-----	57, 500. 00
Cash balance June 30, 1923-----	11, 531. 63
Total -----	441, 676. 90

All payments are made by check, signed by the Secretary of the Institution, on the Treasurer of the United States, and all revenues are deposited to the credit of the same account, except in some instances small deposits are placed in bank for convenience of collection and later are withdrawn in round amounts and deposited in the Treasury.

The practice of investing temporarily idle funds in time deposits has proven satisfactory. During the year the interest derived from this source, together with other similar items, has resulted in a total of \$1,732.50.

The following appropriations were intrusted by Congress to the care of the Smithsonian Institution for the fiscal year 1923:

Bureau:	Appropriation
International Exchanges-----	\$45,000
American Ethnology-----	44,000
International Catalogue of Scientific Literature-----	7,500
Astrophysical Observatory-----	15,500
National Museum—	
Furniture and fixtures-----	\$20,000
Heating and lighting-----	73,000
Preservation of collections-----	312,620
Building repairs-----	10,000
Books-----	2,000
Postage-----	500
	<hr/> 418,120
National Gallery of Art-----	15,000
National Zoological Park-----	125,000
Increase of compensation-----	109,044
Printing and binding-----	77,400
	<hr/>
Total-----	856,564

Respectfully submitted.

GEO. GRAY,
HENRY WHITE,
FREDERIC A. DELANO,
Executive Committee.

PROCEEDINGS OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION FOR THE FISCAL YEAR ENDED JUNE 30, 1923

ANNUAL MEETING, DECEMBER 14, 1922

Present: The Hon. Calvin Coolidge, Vice President of the United States, chancellor, in the chair; Chief Justice William H. Taft; Senator Henry Cabot Lodge; Representative Frank L. Greene; Representative Albert Johnson; Mr. Charles F. Choate, jr.; Mr. John B. Henderson; Mr. Henry White; Mr. Robert S. Brookings; and the secretary, Dr. Charles D. Walcott.

DEATH OF REGENTS

The secretary announced the death, since the last annual meeting, of Representative John A. Elston.

On motion of Mr. Johnson, the following resolution was adopted:

Whereas the Board of Regents of the Smithsonian Institution having learned of the death, in December, 1921, of the Honorable John A. Elston, a Member of the House of Representatives, and a regent of the Institution since January 9, 1920: Therefore be it

Resolved, That the board desire here to record their sorrow at the loss of a colleague whose untimely death terminated a career filled with promise, and whose interest in the affairs of the Institution made him a valued member of the board.

The secretary also announced the death of the Hon. Lemuel P. Padgett, who had been reappointed a regent by the Speaker of the House of Representatives on January 4, 1922.

On motion of Mr. Greene, the following resolution was adopted:

Whereas the Board of Regents of the Smithsonian Institution having learned of the death, on August 2, 1922, of the Honorable Lemuel P. Padgett, a Member of the House of Representatives, and a regent of the Institution since December 15, 1917: Therefore be it

Resolved, That the board here place on record their deep sense of loss at the passing away of their associate, whose career as citizen and statesman was distinguished by lofty purpose and fulfillment, and whose wise counsel in the deliberations of the board will be greatly missed.

DEATH OF FORMER REGENT

The secretary stated that Dr. A. Graham Bell attended the last annual meeting of the board, although not in robust health; that his fourth term as a regent expired on February 20, 1922, thus completing 24 years of service; and that he had decided not to

accept another term. Doctor Bell's illness terminated fatally on August 2 at his home in Baddeck, Nova Scotia.

In view of Doctor Bell's long service as a regent, it was suggested that there be included in the records of the board a suitable brief memorial of his life and work.

The Chief Justice then presented the following resolution, which was adopted:

Resolved, That the executive committee be requested to prepare a memorial commemorative of the life and work of Dr. Alexander Graham Bell, regent of the Smithsonian Institution from 1898 to 1922, said memorial to be presented at the next annual meeting of the board.

NEW REGENTS

The secretary announced the following appointments of regents by the Speaker of the House of Representatives:

On January 4, 1922, the Hon. Frank L. Greene, of Vermont; reappointment.

On January 4, 1922, the Hon. Albert Johnson, of the State of Washington, to succeed the late John A. Elston.

On December 7, 1922, the Hon. Robert Walton Moore, of Virginia, to succeed the late Lemuel P. Padgett.

A joint resolution providing for the appointment of Mr. John A. Roebling, of New Jersey, to fill the vacancy created by the expiration of Doctor Bell's term, had been passed by the Senate and referred to the House of Representatives, but Mr. Roebling declined the appointment on account of poor health.

VACANCY IN THE MEMBERSHIP OF THE EXECUTIVE COMMITTEE

The secretary stated that the expiration of Doctor Bell's term as a regent had caused a vacancy in the membership of the executive committee, and that, under a resolution of the board of regents, adopted December 10, 1914, the chancellor had appointed Mr. John B. Henderson to fill the vacancy "until the next regular meeting of the board."

On motion of Mr. White, the following resolution was adopted:

Resolved, That the temporary appointment of Mr. John B. Henderson as a member of the executive committee be approved and continued until the expiration of his term as regent.

RESOLUTION RELATIVE TO INCOME AND EXPENDITURE

Mr. White, as acting chairman of the executive committee, submitted the following resolution, which was adopted:

Resolved, That the income of the Institution for the fiscal year ending June 30, 1924, be appropriated for the service of the Institution, to be expended by the secretary with the advice of the executive committee, with full discretion on the part of the secretary as to items.

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE

The annual report of the executive committee for the fiscal year ending June 30, 1922, in printed form, was submitted by the secretary.

On motion, the report was accepted.

ANNUAL REPORT OF THE PERMANENT COMMITTEE

This report was read by the secretary, as follows:

Hodgkins fund.—As stated in previous reports, \$5,000 is allotted annually from the Hodgkins specific fund for the maintenance of an astrophysical station on the Montezuma Mountain, in Chile, where studies in solar radiation are being carried on continuously. The work is under the direction of Dr. Charles G. Abbot, Assistant Secretary of the Institution and Director of the Astrophysical Observatory.

Roebeling contribution.—Mr. John A. Roebeling, of New Jersey, has contributed further funds to advance the work of solar research stations in Chile and Arizona and the publication of results there attained. The contributions of Mr. Roebeling to date for this work aggregate more than \$40,000.

Avery bequest.—All the real estate covered by this bequest has been sold. The Avery fund now amounts to \$41,283.

Poore bequest.—This bequest has reached the sum of \$36,025. Under the testator's will, the fund must total \$250,000 before its income shall be available. Several lots of land in the city of Lowell remain undisposed of, but will be sold as opportunity offers. A request has been made that the taxes on this property be abated, but it has not yet been acted upon.

Freer bequest.—A note for \$200,000 given for the purpose of liquidating Federal and inheritance taxes against the estate has been reduced to \$79,250. A balance of \$28,051.05 remains under the building fund and there are several specific accounts with balances sufficient to meet current requirements.

Virginia Purdy Bacon bequest.—This bequest was given to establish the Walter Rathbone Bacon (traveling) scholarship for the study of the fauna of "countries other than the United States." The invested fund now amounts to \$48,300.

Bruce Hughes bequest.—This bequest, which was given to establish the Hughes alcove, has been settled and amounts to \$11,604.53.

Frances Lea Chamberlain fund.—Founded by Dr. Leander T. Chamberlain as a memorial to his wife, Frances Lea. It amounts to \$35,000, and the income is expended in the improvement and increase of the Isaac Lea collections of "Mollusks" and of "Gems and gem material," both in the National Museum.

Walcott fund.—The income of this fund, established by Charles D. and Mary Vaux Walcott, is to be used for research and publication, and as time goes on for such purposes as may be designated by the Board of Regents. The present market value of the securities deposited amounts to \$10,460.

Addison T. Reid bequest.—This bequest, which is to found a chair in biology as a memorial to the testator's grandfather, Asher Tunis, now amounts to \$15,079. The bequest was subject to the condition that the income was to be paid in three shares to certain named beneficiaries until their death. Two of these shares have been received and the remaining share will represent approximately \$5,000.

Residual bequests.—No change has occurred in the status of the following estates, of which the Institution will become the residuary legatee, subject to the death of certain specified beneficiaries:

The Joseph White Sprague bequest.

The Lucy Hunter Baird bequest.

The Riter Fitzgerald bequest.

The Caroline Henry bequest.

Consolidated fund.—This fund is composed of miscellaneous bequests and moneys received in excess of \$1,000,000, deposited in the United States Treasury under the authority of the organic act. During the year several small bequests have been added to the consolidated fund, which now aggregates \$179,390.28.

On motion of Mr. Johnson, the following resolution was adopted:

Resolved, That the Board of Regents of the Smithsonian Institution accepts the annual report of the permanent committee just read and approves and ratifies the actions taken by the committee since the last annual meeting.

ANNUAL REPORT OF THE SECRETARY

In submitting his annual report for the fiscal year ending June 30, 1922, the secretary stated that since the last annual meeting of the Regents 131 publications, comprising 7,785 pages, have been issued by the Institution and its branches. The general appendix to the annual report of the board to Congress contains a selection of popular illustrated articles describing recent advances in nearly every branch of science, and the demand for the report soon exhausts the edition of 10,000 copies.

On motion, the secretary's report was accepted.

ANNUAL REPORT OF THE NATIONAL GALLERY OF ART COMMISSION

The annual meeting of the commission was held December 12, 1922, at which it was voted to recommend to the Board of Regents the appointment for a full term of four years of Messrs. Herbert Adams, Gari Melchers, and Charles Moore, their one-year terms having expired. Messrs. Moore, Adams, and Parmelee were elected by the commission to succeed themselves as members of the executive committee.

The report of the National Gallery of Art for the year was submitted, as were also reports of the standing, special, and subcommittees.

Messrs. E. W. Redfield, W. H. Holmes, and Gari Melchers were appointed a committee to look after the interests of the National Gallery in connection with the final disposition of purchases by the National Academy of Design to be made under the Ranger bequest fund.

The urgent need of a National Gallery building was emphasized and discussion took place as to the advisability of applying to Con-

gress for legislation to have the building project included in the program now being formulated for prospective buildings.

On motion the report was accepted.

Senator Lodge offered the following resolution, which was adopted:

Resolved, That the Board of Regents of the Smithsonian Institution hereby elects Messrs. Herbert Adams, Gari Melchers, and Charles Moore as members of the National Gallery of Art Commission for the full term of four years, their present one-year terms having expired December 14, 1922.

NEW BUILDING

The secretary spoke of the need of space for the proper installation and exhibit of the Institution's art and history collections, and expressed the hope that a new building would be provided to meet this need. No formal action was asked.

FREER GALLERY OF ART

Work is being pushed as rapidly as possible in preparing the collections, which it is hoped will be opened to the public in the coming spring.

EXPEDITIONS

Through the generosity of Dr. W. L. Abbott, of Philadelphia, Pa., Mr. Charles M. Hoy continued his work of collecting for the Museum specimens of the very interesting fauna of Australia. The work was terminated during the winter and Mr. Hoy returned to the United States in May, 1922. The specimens received during the year bring the total up to 1,179 mammals, including series of skeletal and embryological material; 928 birds with 41 additional examples in alcohol, and smaller collections of reptiles, amphibians, insects, marine specimens, etc.

Dr. Abbott's unfailing interest in the national collections is shown by the fact that he has now arranged to send Mr. Hoy to China for the purpose of obtaining vertebrates from certain especially important localities in the Yangtze Valley, a region with which Mr. Hoy has been familiar for many years.

Acknowledgment is made of Doctor Abbott's generosity in financing previous explorations, and it is thought proper to state that up to date he has contributed \$31,500 for the expeditions to Borneo, Celibes, Australia, and China, in addition to which he has contributed largely from the results of his personal efforts in Haiti and elsewhere.

In the summer of 1921 Mr. A. de C. Sowerby returned to China to continue the work of exploration interrupted by the war. This

work, which is made possible by the generosity of Mr. Robert S. Clark, of New York, will now be carried on in the region south of the Yangtze, and the zoological results will come to the National Museum.

Secretary Walcott, accompanied by Mrs. Walcott, continued his geological work in the Canadian Rockies. Notwithstanding bad weather and forest fires, the season was very successful.

THE SECRETARY'S SUPPLEMENTAL STATEMENT

The secretary presented a supplemental statement covering the activities of the various branches of the Institution since the printing of the annual report of June 30, 1922. These will be described in detail in the annual report for 1923.

REGULAR MEETING, FEBRUARY 8, 1923

Present: The Hon. Calvin Coolidge, Vice President of the United States, chancellor, in the chair; the Hon. William H. Taft, Chief Justice of the United States; Senator Henry Cabot Lodge; Senator Medill McCormick; Senator A. Owsley Stanley; Representative Frank L. Greene; Representative Albert Johnson; Representative R. Walton Moore; Mr. Irwin B. Laughlin; and the secretary, Dr. Charles D. Walcott.

DEATH OF REGENT

The secretary announced the sudden death of Mr. John B. Henderson, who had attended the last meeting of the board.

Senator Lodge offered the following resolutions, which were adopted:

Whereas the Board of Regents of the Smithsonian Institution having learned of the death, on January 4, 1923, of John Brooks Henderson, a regent since March 1, 1911, and since May last a member of the executive committee:

Resolved, That the board desire here to record that in the passing away of their colleague biological science has lost an earnest worker, the Institution a generous donor and ardent well-wisher, and the members of this board a valued adviser and lovable friend.

Resolved, That these resolutions be made a part of the records of the board, and that a copy thereof be transmitted to the family of Mr. Henderson as an expression of the profound sorrow felt at his untimely death.

APPOINTMENT OF REGENTS

The secretary stated that the President, on January 22, 1923, had approved a joint resolution reappointing Mr. Henry White; and another appointing Mr. Irwin B. Laughlin, of Pennsylvania, in place of Dr. A. Graham Bell, and Mr. Frederic A. Delano, of the District of Columbia, to succeed Mr. John B. Henderson, deceased.

VACANCIES ON THE EXECUTIVE COMMITTEE

The secretary stated that the expiration of Mr. White's term as a Regent and the death of Mr. Henderson had caused two vacancies in the executive committee, and that under a resolution adopted December 10, 1914, the chancellor had appointed Mr. White and Mr. Delano to serve "until the next regular meeting of the board." These temporary appointments terminated with this meeting, and it was necessary that the board take action to fill the vacancies permanently.

Mr. Greene then offered the following resolution, which was adopted:

Resolved, That the temporary appointments by the chancellor of Mr. White and Mr. Delano as members of the executive committee be approved, and that their membership on said committee be continued until the expiration of their terms as Regents.

FINANCES OF THE INSTITUTION

The secretary placed before the board a number of financial tables showing the resources of the Institution and the allotments for carrying on its work; and urged the necessity for an increase of the appropriations and of the Parent fund in order to provide for the necessary extension of the Institution's activities.

REPORT OF SPECIAL COMMITTEE

Senator Lodge, chairman, presented the report of a special committee approving drafts of a folder and a pamphlet intended for wide distribution outlining the origin and purposes of the Institution, its various activities and resources, and its needs for the extension of its work. The report also contained a recommendation on the question of the proposed recognition of the Institution's benefactors and patrons.

The report was adopted.

NEW BUILDING FOR ART AND HISTORY COLLECTIONS

The secretary reminded the board that at the December meeting he had called attention to the need for another museum building for the exhibition of the Institution's art and history collections. He stated that he had taken this matter up with the congressional members of the board, and that through their efforts an amendment had been attached to the appropriations for the bureaus under the Institution, setting aside a site in the northeast corner of the Smithsonian grounds. The act as passed by the House and Senate is as follows:

The Regents of the Smithsonian Institution are authorized to prepare preliminary plans for a suitable fireproof building with granite fronts for the National Gallery of Art, including the National Portrait Gallery and the history collections of the United States National Museum, said building to be

erected when funds from gifts or bequests are in the possession of the said Regents, in sections or completely, on the north side of the Mall between the Natural History Building, United States National Museum, and Seventh Street, leaving a space between it and the latter of not less than one hundred feet and a space of not less than one hundred feet between it and Seventh Street, with its south front on a line with the south front of the said Natural History Building.

The secretary added that it was his hope that the more progressive American people would become interested in the development of the National Gallery of Art and the history collections and in the provision of a suitable building to be erected on the site granted by Congress.

HAMILTON FUND

The secretary stated that on January 23, 1895, the Board of Regents adopted a resolution increasing the Hamilton fund from \$1,000 to \$2,000 by the addition of accrued interest. He explained that the increased fund yielded only a small income, and that it was difficult to secure the services of suitable persons to give lectures worth publishing, and also that there was another \$1,000 in accrued interest, and he recommended that the fund be increased from \$2,000 to \$3,000 by the addition of this sum.

Senator Lodge offered the following resolution, which was adopted:

Resolved, That the secretary be authorized to increase the Hamilton fund from two thousand to three thousand dollars by the addition of accrued interest.

Other matters of interest and importance to the Institution were considered and acted upon.

PROPOSED MUSEUM OF ARCHITECTURE

Senator Lodge brought before the board a letter from Mr. Horace W. Peaslee, chairman of the Architects' Advisory Council, on the subject of a proposed museum where examples of the best architectural work of past generations could be preserved and urging that the Smithsonian Institution should provide for such exhibits.

The secretary said that the matter had already been brought to his attention but that the lack of funds would preclude any extended arrangement at present.

After some discussion, Senator Lodge offered the following resolution, which was adopted:

Resolved, That the matter of the proposed museum of architecture be referred to the National Gallery of Art Commission for consideration and recommendation at the annual meeting of the Board of Regents to be held December 13, 1923.

GENERAL APPENDIX
TO THE
SMITHSONIAN REPORT FOR 1923

ADVERTISEMENT

The object of the GENERAL APPENDIX to the Annual Report of the Smithsonian Institution is to furnish brief accounts of scientific discovery in particular directions; reports of investigations made by collaborators of the Institution; and memoirs of a general character or on special topics that are of interest or value to the numerous correspondents of the Institution.

It has been a prominent object of the Board of Regents of the Smithsonian Institution from a very early date to enrich the annual report required of them by law with memoirs illustrating the more remarkable and important developments in physical and biological discovery, as well as showing the general character of the operations of the Institution; and, during the greater part of its history, this purpose has been carried out largely by the publication of such papers as would possess an interest to all attracted by scientific progress.

In 1880, induced in part by the discontinuance of an annual summary of progress which for 30 years previous had been issued by well-known private publishing firms, the secretary had a series of abstracts prepared by competent collaborators, showing concisely the prominent features of recent scientific progress in astronomy, geology, meteorology, physics, chemistry, mineralogy, botany, zoology, and anthropology. This latter plan was continued, though not altogether satisfactorily, down to and including the year 1888.

In the report for 1889 a return was made to the earlier method of presenting a miscellaneous selection of papers (some of them original) embracing a considerable range of scientific investigation and discussion. This method has been continued in the present report for 1923.

THE CONSTITUTION AND EVOLUTION OF THE STARS¹

By HENRY NORRIS RUSSELL

The preceding lectures have, I hope, presented to you a picture—drawn rather in outline, owing to the limitations of time—of the stars as they are known at present, their dimensions, masses, densities, surface brightness, and the like. It remains to speak of what has been done to correlate these facts into a theory of the constitution of the stars, and their probable evolution and age.

What makes this problem tractable, in spite of the limitations imposed by the remoteness of the stars in space, and our ephemeral duration in time, is that we have to deal only with the simpler and more general properties of matter. The vast variety of the forms of rock and mountain depends upon the solidity of their materials; the still greater diversity of the forms of organic life is based on the presence of chemical compounds of great complexity—and neither of these conditions can exist at all in bodies as hot as even the coolest stars. In the stars all matter must be gaseous, and the laws of gases are among the simplest known to physics. Add to them the still more general laws that govern gravitation, radiation, and the structure of atoms, and we have the controlling factors in the evolution of the stars.

Considering a star, then, as a mass of gas, isolated in space, we notice first that it must be in internal equilibrium under its own gravitation. The weight of the overlying layers produces a pressure, increasing steadily from the surface to the center, which must at any point be balanced by the expansive tendency of the gas, arising from its high temperature. The temperature, too, is greatest at the center, and decreases toward the surface. Hence, heat must flow continually through the star's substance, down the temperature gradient, till it escapes by radiation at the surface. The supply of heat must be kept up in some way; and one obvious process, as Helmholtz suggested long ago, is the slow contraction of the star. The work done by the gravitational forces in pulling the outer parts of the star toward the center reappears as heat produced by the compression, and maintains the star as a going concern. As the

¹ Reprinted by permission from the Rice Institute Pamphlet, Vol. IX, No. 2, April, 1922. This is the last of a series of three lectures delivered by Doctor Russell at the Rice Institute.

star contracts, its density must increase; and the pressure will increase too, for the various parts of the mass are nearer one another, and attract one another more strongly. When the star has shrunk to half its original diameter, the mean density will be eight times as great.

If the star, after contraction, continues to be "built on the same model," so to speak—that is, if the law according to which the density increases proportionally toward the center remains the same, except for the altered scale of miles provided by the shortened radius, the density at any point, after contraction, will also be eight times the original density at the corresponding point (distant from the center by the same fraction of the radius).

How will the pressures at the two points compare? The portion of the star nearer the center than the point under consideration is compressed by the weight of the overlying portions. After the contraction, every part of these is twice as near the center as before, and will, therefore, be attracted four times more strongly. The whole compressive force will, therefore, be four times as great as at first; but the area over which this force is distributed will have shrunk to one-fourth of its former amount. Hence the pressure per unit of area will increase sixteenfold, as against an eight-fold increase of density. Applying the familiar laws of gases, we find that the temperature of the gas, after contraction, must be twice its original value in order that equilibrium shall still exist when the star has shrunk to half its former size. More generally, during the whole process of contraction, the temperatures at corresponding points will be inversely proportional to the star's radius—so long, indeed, as the star continues to be built on the same model, and the simple gas laws hold good. This proportion was first proved by Lane of Washington, in 1870, and is known as Lane's law.

It appears at first sight paradoxical that a star may grow hotter by losing heat; but the difficulty disappears when it is realized that the heat produced by the contraction exceeds the amount which is required to raise the temperature of the mass to the extent demanded by Lane's law. The remainder is available for radiation, and it is only as it is gradually lost into space that the process of contraction can take place. The manner in which the surface temperature of a star, which determines its color and spectral type, will vary as it contracts is somewhat different. As has already been shown, the light from the far interior of a star stands no chance of getting out to the surface, but practically all of it will be scattered away by the gases through which it passes, and remain inside the star. Light can only reach us directly from a relatively shallow layer close to the surface, and it is a certain sort of average of the

temperatures throughout this layer that gives the effective surface temperature. As the density of the star varies, the depth of this layer will alter, and in such a way that it always contains the same number of tons of material per square foot, since it is upon this quantity that the amount of scattering of light passing through the layer depends. As the star contracts, the total quantity of matter in this superficial radiating layer will therefore diminish proportionally to the surface area; that is, the radiating layer will form an ever decreasing part of the whole mass of the star, and its depth will be a smaller fraction of the star's radius. If the depth were a fixed fraction of the radius, we could apply the law of corresponding points and say that the temperature would vary inversely as the radius; but, in fact, after contraction the new radiating layer will form only the upper portion of the layer which "corresponds" to the old radiating layer, and its average temperature will be lower than that of the "corresponding" layer. On any reasonable assumptions regarding the way in which the temperature varies in the outer part of the star, it is found that the effective temperature of the surface will increase as it contracts, but much more slowly than the central temperature.

All these conclusions are based upon the fundamental assumption that the simple gas laws hold good throughout the star. This may safely be assumed if the density is low—say, not more than 20 times that of air—but when the density begins to approach that of water, it will certainly be very far from the truth. As the density increases, the compressibility diminishes, so that, at the same temperature, it takes a greater increase of pressure to produce a further increase of density than would be necessary in a perfect gas. In other words, the material is better able than a perfect gas to stand up under pressure. Hence, referring to the argument by which Lane's law was proved, we see that a smaller increase of temperature than is demanded by this law will enable it to meet the changing conditions resulting from contraction. Indeed, a point will in time be reached when no further rise of temperature at all is needed, the decreased compressibility of the dense gas taking the whole load. Beyond this the increased pressure due to contraction acting alone will be insufficient to produce the necessary increase in density, and a fall in temperature must complete the adjustment.

We see, therefore, that a sphere of real gas, contracting under its own gravitation, will follow Lane's law only while its density is small. As it contracts further its temperature will rise more slowly than this law indicates, reach a maximum, and then gradually diminish. During this long process, the model upon which the mass is built will itself gradually change—the increase of density toward the center diminishing—but this will not alter the general

character of the phenomena. We may at least say with confidence that the surface temperature, as well as that in the interior, will reach a maximum and then diminish, until at last the mass will shrink nearly to the greatest density which it can possibly attain, and end by cooling off almost like a solid body. During the early stages, while the temperature is rising, the body will be of large diameter. As it contracts its surface will diminish, but its surface brightness will increase, so that the amount of light which it gives out will not change much. It will, however, grow whiter as it gets hotter, until it reaches its maximum attainable temperature. By this time it will be much smaller in diameter than at the start, but only a little fainter. But after it begins to fall in temperature, while still contracting, the situation is different. There are now fewer square miles in its surface, and less light given out per square mile, so that its light will fall off rapidly, and it will grow fainter and redder until at last it disappears.

During its history, therefore, it will pass through any surface temperature lower than the maximum twice—once when of large diameter, low density, great luminosity, and rising temperature, and again when its diameter is small, density high, luminosity low, and temperature falling. It is obvious that these contrasted groups of characteristics are exactly those which differentiate the giant and dwarf stars. The theoretical and observed pictures, indeed, agree not merely in their general outlines, but in every detail. For example, the lower the temperature selected for study, the greater will be the theoretical difference between the groups of stars of rising and falling temperature, and the greater is the actual difference between the giant and dwarf stars. The approximate equality in brightness among the giant stars of the various spectral classes, and the great differences among the dwarfs, find also a complete explanation.

Stars of large mass, as can easily be shown, should attain a greater maximum temperature than those whose mass is smaller, and should be more luminous than the latter, for the same surface temperature, especially in the giant stages. The great masses and luminosities of the B stars are thus accounted for. They are not massive because they are hot, but hot because they are massive. Lesser masses never attain the B stage of temperature, but stop at A; and still smaller ones may not get beyond class F, or even G. As we go down the spectral series, therefore, we are continually adding to our list stars of mass too small to get into any of our earlier groups at all—so it is no wonder that the average mass decreases for the redder stars. The fact that the masses of the giants average high, whatever their spectral type, is probably an effect of observational selection. We have picked them from a list of naked-eye stars, and hence from one

in which the brighter stars have an egregious preference, and it has already been seen that, in these stages, great brightness means large mass.

A more searching test is found in the densities of stars of the various sorts; for here we can make our comparison quantitative instead of merely qualitative. The stars of increasing temperature should have densities at which the simple gas laws can be trusted to apply, at least approximately; the dwarfs should be so dense that we can be sure that these laws fail of application; while the hottest stars should have an intermediate density corresponding to the region in which the gas laws are strikingly at work. From a general knowledge of the properties of matter, we can say with certainty that a density less than ten times that of air falls in the first class, one greater than that of water in the second, while the "twilight zone" between corresponds to densities in the neighborhood of one-tenth to one-quarter that of water, and perhaps a little higher. Now we have already seen that the redder giant stars are less dense than air—the whiter ones being probably from ten to fifty times denser; that the average density of the A stars is one-fifth that of the sun, or one-third that of water, while their individual densities range from about fifty times that of air to that of water, and that the dwarf stars have densities running from about that of water up to four or five times as much. The agreement is perfect throughout and there can be no remaining doubt that the proposed physical model represents what actually happens in the stars.

This theory of stellar evolution was first propounded by Sir Norman Lockyer, who outlines clearly the physical processes involved. His criteria for distinguishing between stars of rising and falling temperature were spectroscopic, and chosen in a rather arbitrary way, with little explanation (though they were not very far from anticipating Adams' later discovery), and his views failed of general acceptance. It fell to the speaker's lot, some years later, to revive the theory, and point out the importance of the absolute magnitudes, which, indeed, furnish the key to the whole problem. This invaluable aid was not available when Lockyer began his work—for in those days little indeed was known of stellar parallaxes—so that it is not surprising that his individual assignments of stars to the classes of rising and falling temperature are often erroneous. With the wealth of material now available, it is an easy matter to point out stars in every successive stage of evolution, and to assign the large majority of those for which we have data to their place in its sequence. Mention should again be made, however, of the few, faint, but perplexing white stars of low luminosity.

These do not fit into the scheme at all, and they present such an extraordinary combination of high temperature, small luminosity, and considerable mass that it is very difficult to form any consistent idea of the physical conditions which exist on their surfaces. There are indeed more worlds for theory to conquer—and some of them look as if it would take hard fighting.

But there are other ways in which our knowledge of the properties of matter may be applied to the stars. A simple calculation shows that the gravitational pressure at the center of the sun must be something like a hundred million tons per square inch. The pressures in other dwarf stars are of the same order of magnitude. Those in giant stars are smaller, but are usually measurable in thousands of tons per square inch, even when the density can not be many times greater than that of air. To withstand such a pressure, at this density, the gas must have a temperature of many millions of degrees.

What can we say of the properties which matter would exhibit at these temperatures? Twenty years ago the only answer would have been, "Very little"; but now, with our knowledge of atomic structure, we can say a good deal. The extreme violence of the collisions between the atoms would knock off all the electrons of the outer shells, and keep them off. The lighter atoms—perhaps as far as sodium or even beyond—would lose all their electrons, and be reduced to bare nuclei. The heavier ones would retain their innermost one or two rings or shells of electrons, but lose the outer ones, which contain a considerable majority of the whole number of electrons originally present. We can be certain, however, that the nuclei themselves would emerge quite unscathed from these collisions, and that if an isolated nucleus, or the battered fragment of a heavier atom, had a brief interval of relative quiet it would begin to pick up electrons again from those which passed by slowly enough, and to reconstitute the atomic structure. Could we remove a portion of the matter in this strange state and let it cool, the familiar atoms would thereupon rebuild themselves, bit by bit, and at the end they would be the same as ever.

The principal differences at the high temperature, from our present standpoint, are, first, there would be a vast multitude of free electrons flying about, as well as the far heavier atomic nuclei, so that the average "molecular weight"—in determining which every free-moving particle in the gas counts as much as any other—would be much diminished. Secondly, the gas at this temperature would emit a tremendous flood of radiation, most of it of such short wave length that it would resemble X rays rather than ordinary light. This radiation would not go very far before it was scattered

in all directions by the electrons, or absorbed in detaching some fast-knit electron from the remnant of an atom, only to be re-emitted when recombination took place. In either case the energy would be relayed back and forth from atom to atom, now in this direction, again in that, until in the lapse of ages it leaked gradually outward to the cooler parts of the star, on its way to the surface.

Jeans was, I believe, the first to call attention to this extraordinary state of things, and Schwarzschild to point out the fundamental importance of the exchange of radiation in determining the conditions of equilibrium within a star; but the general solution of the problem came later, from Eddington, who was the first to appreciate one of its most fundamental features.

The flood of entrapped radiation, in its attempts to escape, exerts a pressure outward in all directions, just as a compressed gas would do. The existence of this radiation pressure was pointed out long ago by Maxwell's theory of light. With any light obtainable on earth, even full sunlight, it is so minute that apparatus of the most delicate sort is required to indicate its existence; but at the temperatures which prevail inside the stars it may amount (as Eddington pointed out) to hundreds of tons per square inch and be an important factor in preventing the collapse of the star's interior under the weight of the outer parts. Indeed, under some conditions, it may do more than the gas pressure due to the motions of the atoms and electrons, huge as the latter is. Following this lead, and working out the laws of flow of energy outward down the temperature gradient, he showed that certain simple and probable assumptions about the opacity of the medium led to the conclusion that, all through the star, the gravitational pressure would be proportional to the fourth power of the temperature, and that the shares of this pressure which were sustained by the gas pressure and the radiation pressure would be everywhere in the same ratio. These conditions, combined with the law of gravitation and the gas laws, suffice to determine completely the model upon which the star is built, and to tell us practically all that we need to know about it.

For the case where the simple gas laws hold, the mathematical work had already been done by Emden, who found that the outer regions of the star were of very low density, while there was a rapid concentration toward the center, where the density reaches fifty-four times the mean density. The central temperature of such a star obeys Lane's law, while the surface brightness varies inversely in the square root of the radius. This means that the whole amount of energy radiated from the star's surface will be independent of its size—the increase in surface brightness and decrease in area, as it contracts, balancing one another exactly. The amount of the star's radiation depends upon the opacity of its material—diminishing as

this increases—and is also proportional to the ratio which the radiation pressure bears to the total pressure at any part inside the star. This ratio increases rapidly with the star's mass, and the brightness should do the same.

These conclusions form a theory of giant stars. To extend it to dwarf stars Eddington repeated his calculations, taking into account the manner in which the compressibility of a gas decreases with increasing density, and obtained a theoretical table which represents the way in which the absolute magnitude and temperature of a star should depend upon its mass and density throughout the whole range of these quantities. This table reproduces the actual characteristics of the dwarf stars and those of maximum temperature, as well as the giants, with a fidelity which is almost uncanny, and far more than justifies its author's modest claim that the theory upon which it is based "gives a fair approximation to the facts."

But Eddington's theory goes beyond this. It actually shows us why the masses of the stars are so much alike, and why they are of their actual order of magnitude. If β is the fraction of the whole pressure within the star which is balanced by the gas pressure, leaving the fraction $1-\beta$ for the radiation pressure, he derives by reasoning of a very general character, the equation

$$\frac{1-\beta}{\beta^4} = 4.6 \times 10^{-68} M^2$$

where M is the mass of the star in grams. The extraordinarily small numerical coefficient depends only upon a few very fundamental natural constants—the gravitational constant, the quantum, and the average mass of one of the "molecules" in the star (including in this term atoms, nuclei, and free electrons). The numerical value here given depends on the assumption that the last quantity is 2.8 times the mass of a hydrogen atom, an estimate which must be nearly correct if the atoms are dissociated into nuclei and electrons to the degree which has been described.

Now, following Eddington's argument, we may imagine a set of spheres of gas, each isolated in space and in equilibrium under its own gravitation and radiation, the first mass of 10 grams, the next 100 grams, the third 1,000 grams, and so on. Then, by means of his equation, we find that the proportion which the radiation pressure bears to the whole will be quite negligible in all the spheres up to No. 32, will increase rapidly for Nos. 33 and 34; while for sphere 35 and all those beyond it the radiation pressure will be the dominant partner, leaving little for the gas pressure to do.

Upon this long line of spheres, therefore, we find a small region in which a certain natural factor changes from an insignificant to a controlling rôle. On general physical principles, therefore, as Ed-

dington puts it, we would expect "something to happen" in this critical interval, and "what happens is the stars." It is only when the radiation pressure and the gas pressure share the gravitational food that we get anything that can fairly be called a star. Smaller masses do not give out light enough to make them visible at interstellar distances, while the great ones, in which the radiation pressure is almost sufficient to counteract gravitation, would be in an almost unstable condition, so that a small disturbance, such as might be produced by a moderate rotation, would cause them to break up into parts. Hence smaller masses do not shine, and bigger ones break up, and only those in the critical intervening range of mass remain as luminous stars. We have seen that this should occur for masses comparable with those of spheres 33 and 34 of the series. Now the first of these is of half the mass of the sun, and the second has five times the sun's mass, so that the actual masses of the stars fall very exactly into the range indicated by the theory. Since the constants of this theory are derived from those which are the most fundamental in modern physics, we may truthfully say that the masses, and hence the sizes and brightness of the stars are determined directly by the fundamental properties of the very atoms of which they are composed. It may be shown, for example, from Eddington's equation, that a mass of gas will shine as a giant star when, and only when, the ratio of the diameter of the star to the average distance between the atoms which compose it is about 20 times the ratio between the charge of an electron and the average mass of an atom (provided that this mass is measured, not in the ordinary way, but, as in the electrical case, by its power of attracting a similar mass at a given distance). The latter ratio is very large, about 4×10^{17} , so that the number of atoms in the star is enormous, and the star itself a very large mass.

One of the most impressive consequences of the whole theory is that the masses of the stars are determined by the interplay of the two forces, gravitation and radiation pressure, which, among all those in nature, are so feeble, under the conditions of ordinary experiment, that it taxes the skill of the experimenter to build an apparatus delicate enough to measure the effects of either one. Were we confined to experiments in enclosed laboratories, isolated in space, without the earth's attraction to prove to us the existence of gravitation, it would probably have been long before the very existence of either of these forces would have been suspected; yet these forces, and these alone, when working on the grand scale, are powerful enough to shape the stars.

One question still remains. How long a time is required for this sequence of evolutionary changes? What is the life of a star?

Here, again, the answer which we would now give depends upon knowledge which has come within the last decade or two. We have, even now, no direct evidence regarding the age of the stars, or the sun; but we have information about the age of the earth that has magnified our conception of the duration of the universe in time, in as startling a fashion as the study of the globular clusters has enlarged our idea of its extension in space.

The new method of measuring time is really very simple. Uranium is radioactive, and slowly "decays." One by one its atoms eject a part of their nuclei, and change into atoms of a different element. These again break up, and so on through a long and wonderful series of transformations, in which radium is one step. The particle ejected from the nucleus is sometimes an electron, but oftener an alpha particle, identical with the nucleus of a helium atom. Finally, at the end of the list, there remains a stable atom of lead—but not of ordinary lead, for its atomic weight is 206, instead of 207 as usual. In the course of ages, this radio-lead must accumulate in all uranium minerals. The rate of accumulation is accurately known, from a study of radioactive phenomena and we can be sure that the weight of lead produced in a million years is one eight-thousandth of that of the uranium which is present. By determining the percentages of uranium and lead now present in a mineral, and applying this principle, we can find out how old the mineral is—provided, of course, that it contained no lead when it was originally formed by crystallization in the molten rock mass. Such primitive lead would, however, be ordinary lead, of higher atomic weight, and a determination of the atomic weight of the lead derived from our specimen will enable us to tell how much of it was there when the mineral formed, and how much has been produced by radioactivity since this time.

In this way reliable values can be obtained for the ages of various minerals, and the dates of the eruption of the rocks in which they occur. The latter can often be defined in geological terms, and hence we can date the various geologic periods, finding a good general agreement with the geological order of succession. The oldest minerals so far studied are found in rocks of Middle Pre-Cambrian age. Specimens from Europe, Africa, and America agree in giving ages of between 1,000 and 1,200 millions of years. These individual crystals have been in the rocks for all this time. The earth, as a planet, must be older. The speaker, from consideration of the whole amount of uranium and lead in the earth's crust, showed last year that its age is apparently less than eight billions of years, and probably something like 4 billions. If, as seems most probable, the planets were produced by eruptions from the sun, under the tidal

influence of a passing star, the sun itself must have been already formed at that remote epoch.

But we may go further. Life already existed on the earth in Cambrian times, and it is a moderate estimate to say that the process of organic evolution has lasted for a billion years. During all this time the sun can never have been one stellar magnitude brighter or fainter than it is now; for in the first case, its heat would have raised the oceans to the boiling point, and, in the second, they would have frozen solid—and either of these catastrophes would have put an end to evolution and to all terrestrial life. Now the sun is a typical dwarf star, and there is good reason to believe that it is now well advanced in cooling and was once much brighter and hotter than it is now—of class F, at least, though perhaps not of class A. At such a time it must have been at least two magnitudes brighter than at present. Yet in the whole of geological time it has probably decreased half a magnitude or less. We may, therefore, say, with considerable confidence, that the life of the sun, and doubtless also of the stars in general, must extend over many billions of years.

But here we meet with a serious difficulty. We know the rate at which the sun is radiating energy to the earth, and, from consideration of the way in which the earth in turn radiates this energy into space, we can be sure that the sun is also sending out an equal amount of heat into space in every direction. The total output is so great that it would exhaust the whole huge fund of energy which would be made available by the sun's contraction from an indefinitely extended size, in about twenty million years, as Lord Kelvin showed long ago. When we allow for the fact that some of this heat is still stored in the sun's interior, and that it was probably much brighter in its earlier stages of evolution than at present, we see that, if gravitational energy alone was available as the source of its radiation, the sun's past life as a star must have occupied but a very few million years. In view of the geological and radioactive evidence, there seems to be no escape from the conclusion that the sun must have some other, and far greater, store of internal energy upon which to draw.

Further evidence in favor of this view has been found by Eddington in the behavior of the star Delta Cephei. This is a typical giant star, about eight hundred times as bright as the sun. Eddington has given good reason to believe that the cause of its variation in light is a periodic expansion and contraction of the whole star by about 10 per cent on each side of the mean. The period of this change would depend on the density of the star, and diminish if this increased. Hence, if the mean diameter was gradually contracting, the period should shorten. Eddington calculates that, if the radiation is supplied by gravitational contraction alone, the period should

decrease by about 40 seconds per year. The observations, which cover more than a century, show indeed a decrease of period, but at the rate of about a second in 12 years—five hundred times slower than the previous theory would demand. Here again we have evidence that the rate of stellar evolution—in a giant star this time—is many hundreds of times slower than it would be if there was not some internal store of energy to draw upon.

It is certain that no corresponding evolution of heat from any source occurs within the earth, and we must therefore suppose that energy from the “unknown source” becomes available only at exceedingly high temperatures, such as prevail inside the stars. But if this is the case, and a star, in contracting, gets hot enough inside to start this process going, why does this not make the interior still hotter, and so cause a still more rapid transformation of the unknown energy into heat, till the process ends in an explosion on a colossal scale? I mulled over this idea for a couple of years before I saw the simple answer. If heat energy is supplied to the interior of a giant star, the star will have to expand, and if it expands, it must grow cooler. The process is the exact reverse of that by which contraction makes the star hotter, and at the same time compels the escape of heat from the surface into space. Hence, if too much heat is supplied from the unknown source, the star will expand and cool, shutting off further supplies. It is easy to see that we have here a self-regulating process, which, in the long run, will automatically adjust the supply of heat in the interior so that it just makes up the loss due to leakage toward the surface and radiation into space. In the short run, we might find alternate overproduction, leading to expansion of the star and cooling, and underproduction, permitting contraction and heating; and oscillations of just this sort appear to happen in the Cepheid variables. Though the star may thus be kept shining for a very long time, it can not go on forever, for the store of internal energy, however vast, must be finite, and will gradually be used up. As this happens, the star will contract, although very slowly, and ultimately pass through the various giant and dwarf stages, in substantially the manner which was described earlier.

Such a store of available energy will account for the facts; but how shall we attempt to account for the store of energy itself? One thing is clear at the start. The only places small enough to contain so huge an accumulation are the nuclei of the atoms. I say “small” advisedly, for it is only when the constituent parts of which the atoms are built come exceedingly close together that the forces between them can become great enough to account for their possession of such an amount of energy. Radioactive energy, which comes

from atomic nuclei, represents indeed one such gigantic store. But the amount of energy which must once have been stored in each gram of the sun's mass, to account for its past radiation of heat, is even greater than that contained in uranium. We can not do more than guess where it may have been hidden; but one very recent piece of work affords a possible clue.

Aston, in one of the brilliant researches which we have learned to associate with the Cavendish Laboratory at Cambridge, has invented a beautiful apparatus which sorts atoms, by giving them electrical charges and shooting them through a vacuum under the influence of electric and magnetic fields. The resulting forces deflect atoms of different weights in different directions, and bring each kind to a separate focus upon a photographic plate, producing images when the plate is developed. By measuring these plates the atomic weights may be determined; and Aston has found that, in every case but one, the true atomic weights are exact integers, within the accuracy of measurement, which is about 1 part in 1,000. When the chemist finds an atomic weight which is not an integer, such as 35.46 for chlorine, this is really the average for two different kinds of atoms of the same chemical properties, but different weights, both of which are integers—35 and 37 in this case. The one exception is hydrogen, for which the chemist's determination 1.008 is exactly confirmed.

Now it is more than a century since Prout suggested that, since the atomic weights are so nearly integers, the atoms themselves are built up out of simple units. We now transfer this idea to the atomic nuclei, which contain practically all the mass, and Aston's beautiful researches practically compel belief. The hydrogen nucleus, or "proton," is the lightest of all, and we would naturally look to it as the fundamental unit. Rutherford's success in knocking the nuclei of elements such as oxygen, nitrogen, and sodium to bits, by collision with fast-moving alpha particles, has furnished a definite proof that protons, and alpha particles as well, are actual constituents of these nuclei. Many nuclei must also contain electrons, which prevent the net electric charge from getting too high. It looks, for example, as if an alpha particle was built of four protons and two electrons, held together by forces of whose nature we are ignorant. This would give exactly the right electric charge; but the mass of the four protons would be greater than that of the alpha particle by 1 part in 130. (The electrons weigh next to nothing.) This seems to spoil the explanation altogether, but an escape is found in that great resolver of otherwise intractable difficulties, the principle of relativity. According to this, all energy has mass, and all mass is equivalent to energy. The loss of mass in

the formation of the alpha particle would mean that, in forming it, energy would be liberated, which would have to be put back into it again in order to separate the parts. The calculated amount of energy is so enormously great that it is not at all surprising that the alpha particle is so stable. Even in the collisions with other atomic nuclei which shatter the latter into fragments, the forces (which can be roughly calculated) are not nearly strong enough to disintegrate it.

We may now suppose that, in the interior of the stars, and by some process the details of which are still quite unknown, the atoms of hydrogen are taken apart, and the pieces—protons and electrons—built up into the nuclei of heavier atoms, with just enough electrons left over to build the outer parts of these. We can not be sure, of course, that such a thing actually happens; but if it does, the energy liberated will suffice for the present demands of astrophysics. If the sun, for example, was originally all hydrogen, which was transformed in this fashion into other elements, the energy which would be set free as a by-product would keep it shining at the present rate for about 120 billions of years.

Such is our present conception of the stars, their distance, their age, their nature, and their life history. In the grandeur of its sweep in space and time, and the beauty and simplicity of the relations which it discloses between the greatest and the smallest things of which we know, it reveals as perhaps nothing else does, the majesty of the order about us which we call nature, and, as I believe, of that Power behind the order, of which it is but a passing shadow.

THE SUN AND SUNSPOTS, 1820-1920 ¹

By E. WALTER MAUNDER

[With 7 plates]

The Royal Astronomical Society was founded in 1820. At that date it was known that there was a sun, that sometimes there were spots upon its surface, and that the sun rotated on its axis. Practically that was all.

In 1826, the systematic study of the sun's surface was commenced by Schwabe, and it has been continued up to the present time. Schwabe presented his drawings to the Royal Astronomical Society; and as it also possesses those of some of his predecessors in the same field, this society now holds records of one kind or another showing the changes that have taken place upon the solar surface from the year 1820, and so continuously to the present date.

The question before us this evening is: What views do we now hold of the constitution of the sun and the relationships of its spots, and upon what facts do we base them?

A quarter of an hour is a short time in which to review the scientific evolution of a century, even when the inquiry is restricted to a single department of astronomy, so confined that it deals only with sunspots as drawn at the telescope, or impressed upon the photographic plate.

My first illustration (fig. 1) deals with the annual percentages of spotless days, 1826-1923, and is an extension of that appearing in the *Monthly Notices*, 74, Plate 4, between pages 114 and 115. It is based upon Schwabe's persistent daily count of sunspots. In itself, his work was very simple and straightforward, but it was carried on systematically and with the utmost patience. These qualities made it great and epoch making, and they were acknowledged by the award to him, in 1857, of the gold medal of this society.

The diagram is deduced, partly from the observations of Schwabe; partly from those of R. Wolf; and from 1885 to the present time from the Greenwich Photoheliographic Results. It exhibits for each

¹ An address given on the evening of Monday, May 29, 1922, at the "conversazione" held in connection with the centenary of the Royal Astronomical Society. Reprinted by permission from *Monthly Notices of the Royal Astronomical Society*, Vol. LXXXII, No. 9. With additions.

year from 1826 to 1923 the percentage of the days of observation upon which the sun appeared to be free from spots. It shows clearly that all years are not equally prolific as to sunspots. Confining ourselves to the years represented, it appears that there were eight cycles completed when there was a most marked absence of spots; a ninth cycle being now nearly completed. The dates of such absences are very clearly defined and are marked by the actual year inserted just above the apices. In the ninety-eight years represented there is in no case any doubt as to the year of the greatest solar quiescence, and a simple examination of the curve demonstrates that the average length of the interval, from one year of greatest quiescence to the next, was nearly $11\frac{1}{2}$ years, and that the range in length of that interval was from 10 to 13 years.

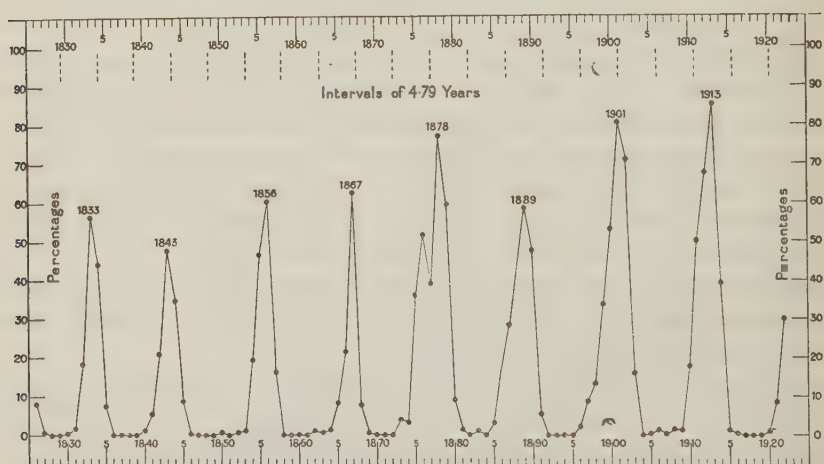


FIG. 1.—Annual percentages of spotless days, 1826–1923

This interval is often spoken of as “the sun-spot period.” The use of the word “period” has been unfortunate, for it has given rise to an impression which is not in accord with the facts of the case. Let us speak of it in future as “the sun-spot cycle.” A series of events may be, and often is, “cyclical” without being in the usual mathematical sense “periodic”; but we are not, at present, justified in applying the term “period,” in its strictest mathematical sense, to the interval that occurs between one sun-spot minimum and the next.

The second illustration (fig. 2) gives a somewhat fuller study, derived from the measures of the areas of sunspots made at Greenwich Observatory on the photographs of the sun, taken during the years 1874–1923; it is an extension of a similar diagram given in the Monthly Notices, 64, page 748. It exhibits the mean daily spotted

area of the sun; the total mean spotted area of the northern hemisphere being shown separately from that of the southern. The principal feature of the diagram therefore is the comparison of the sun-spot areas in the two hemispheres. From this point of view the diagram is worth careful consideration. Just as the first illustration showed that during the years represented there was only one sun-spot cycle—a cycle having a mean duration of about $11\frac{1}{2}$ years—so the present diagram shows that the cycle holds good for each hemisphere, as well as for both together. The solar cycle is one. There is no question of the existence of submultiple cycles, or of incommensurable cycles of greater length.

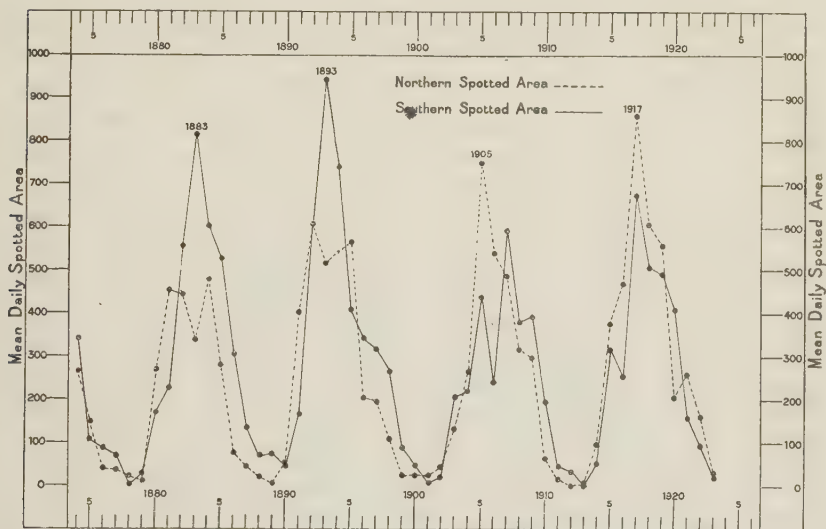


FIG. 2.—Mean daily spotted area, north and south, 1874–1923

Further examination of the diagram shows that the maximum activity in any particular cycle does not necessarily fall at the same epoch for the two hemispheres; rather, a divergency appears between them. In each of the four cycles represented, the northern activity was developed before the southern; in each of them the curve in one hemisphere attained a single crest, while in the other it attained a double one; or, to put it in other words, the form of the curve was not the same in the two hemispheres. We have therefore here a solar dichotomy displayed. Had the results of the whole century been presented in a like form, other peculiarities would have been seen, but these would have strengthened, not weakened, the case for the solar dichotomy. The solar cycle is one; its manifestations in the two hemispheres, north and south, are different.

The third diagram (fig. 3) is an extension of that appearing in the Monthly Notices, 74, Plate 3, between pages 114 and 115, and brings out another relation. The solar dichotomy is not illustrated here; we are dealing with the whole of the sun's disk as we see it. The points set forth are the variations in the area covered by sun-spots, and the variations in the mean distance from the equator of the sun of all spots. Area and latitude are the two factors brought into notice. The period covered by the diagram is 1854–1923. The statistics for the first two cycles are derived from the work of the late Professor Spoerer; for the last four, from the Greenwich Photoheliographic Results.

The continuous line shows the variation in the total daily spotted area of the sun during the progress of each cycle; the dotted line

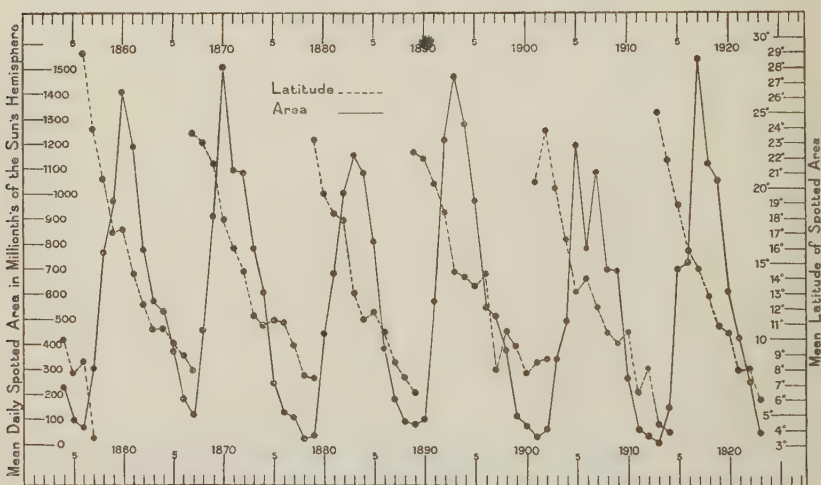


FIG. 3.—Mean latitude and mean spotted area, 1854–1923

shows the changing distance from the solar equator of the center of gravity of the sun-spot zones. In this latter curve, we have the fact that the solar cycle is one, and one only, brought out in a most unmistakable fashion; each cycle begins with an activity in high latitude; each cycle ends with the last remnants of activity transferred to a low one; but, as the new cycle begins before the old cycle has completed its course, the two overlap for a short time. This is what is known as "Spoerer's law of zones." Broadly speaking, we may say that the approach toward the equator is continuous from the beginning of the cycle to its end. The distinction between the forms of the two curves is emphatic. The area curve is continuous; it begins practically at zero; it increases up to a certain point; it then diminishes again to the next zero; and so on. Flow and ebb, flow and ebb, follow each other continuously. But the latitude curve is dis-

continuous. It always starts from high latitude; when it has reached low latitudes it is cut off; there is no gradual return to the high latitudes. The reappearance of spots in high latitudes is sudden.

There are now three facts before us. There is one solar cycle, shown differently, in time and form of the curve, in the two hemispheres, and now in two manifestations of quite separate character; one in area, a complete pulsation, and one in latitude, which moves in one direction only; i. e., from high solar latitudes to low.

The fourth illustration (fig. 4) appeared in the *Monthly Notices*, 74, Plate 2, between pages 114 and 115. It deals only with the distribution of spots in latitude, nothing being shown concerning the areas of spots. The materials are drawn entirely from the Greenwich Photoheliographic Results, and extend over the years 1874–1913. Seven thousand spots are represented, but the short straight line which indicates the latitude of a spot is drawn just as long and as heavy for a small spot as for a large one; for one spot as for a dozen. All spots occurring during the same rotation of the sun are represented in the same vertical line. The diagram is concerned only with the distribution of spot centers in heliographic latitude.

This diagram has been familiarly called “the butterfly diagram,” as it seems to suggest three butterflies pinned down to a board with their wings extended. Heads, bodies, and legs have disappeared, but the outstretched wings remain. Each pair of wings is distinct from the next; there is a clear V-shaped gap between each of the three specimens. Here again the first deduction is reinforced from an altogether different set of facts. The solar cycle is one.

This diagram further suggests that the *origin* of the solar spots lies within the sun, not without. They come from below the surface; they are not impressed upon the surface by some exterior influence; neither by planets nor by meteors. No exterior influence could invariably begin a fresh disturbance in a high latitude simultaneously on both sides of the Equator.

If we take a card with a narrow slit in it, parallel to the sun's equator, and move it up and down over the diagram, then, wherever that slit is placed within the range of the sun-spot zones, the three sun-spot cycles will be brought out clearly and unmistakably. Our first conclusion, that the sun-spot cycle is one, is now extended; it is true not merely for sunspots in general, but for the spots of any special zone in particular. This conclusion goes deeper than our first, which was merely that the sun-spot cycle, on the average, lasted for about $11\frac{1}{2}$ years. The sun as a whole is under the law of that cycle, and each individual zone has its own particular part to play in it. But the sun as a whole is a unit, no matter how distinct its dichotomy into two hemispheres, no matter how distinct may be the action in any particular zone.

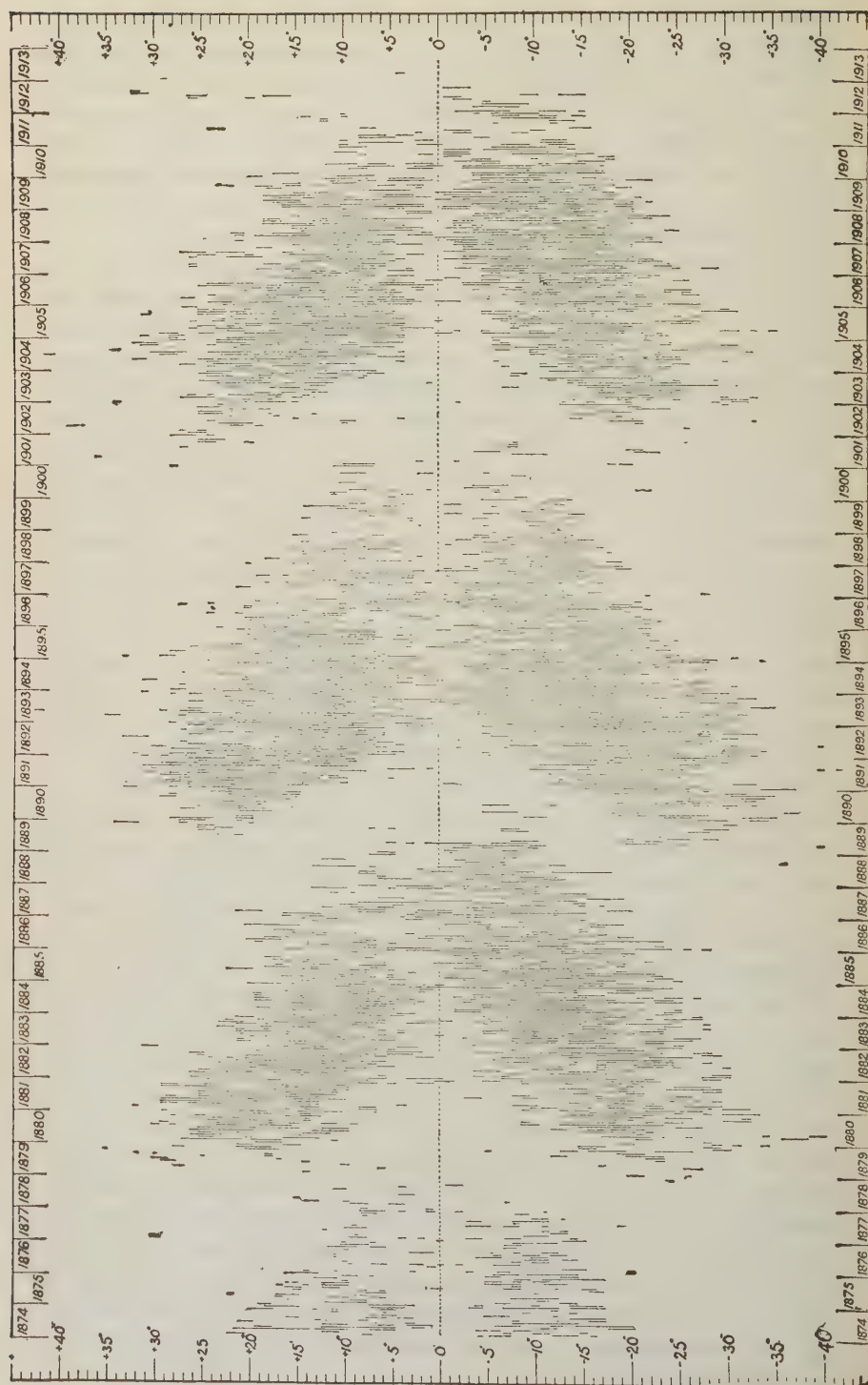


FIG. 4.—Distribution of spot-centers in heliographic latitudes

Another feature is suggested by this diagram, but will be better brought out in a different connection. It is that the southern hemisphere appears to encroach slightly on the northern at the equator, or at about the time of the close of one cycle and the beginning of the next. The southern influence seems to cross the equator.

Since the origin of the solar spots lies within the sun, and the northern and southern spots show differences in their behavior, we must conclude that the sun is not symmetrical in the constitution of its interior. If then we assume, as the basis of any investigation, that the sun is symmetrical in its internal constitution, we are making an assumption contrary to the evidence supplied by the behavior of its surface.

If there be this clear distinction between the two hemispheres, is it possible that one of them might go out of action for a time, and if so, what would follow?

This is not a mere oratorical question; the event supposed has actually occurred. Dr. Rudolf Wolf, of Zurich, demonstrated, and Spoerer developed that demonstration further, that in the latter part of the seventeenth century and the beginning of the eighteenth the northern hemisphere of the sun failed for many years to produce a single recorded spot.

Was there any effect during that same period recognized here on the earth that could be plausibly associated with this failure in spot production in the sun's northern hemisphere?

It is suggestive that, while the northern hemisphere was thus entirely barren, the southern hemisphere of the sun had some spots, but only few, and for nearly 70 years the sun showed a prolonged spot minimum. The failure in spot activity of the northern hemisphere was not compensated by an increased activity in the southern. Further, as Miss Agnes Clerke pointed out in *Knowledge* for September, 1894, no auroræ were reported during these years; from which we may infer that there were no great magnetic disturbances taking place on the earth. It is also suggestive that Prof. A. E. Douglass, who has been studying with great particularity the annual rings of trees in relation to climate and the solar activity (*Climatic Cycles and Tree Growths*), found that this same period "was the interval in the yellow pines" (i. e. of northern Arizona) "which gave me more trouble than any other in trying to work out the action of the sun-spot cycle" (*Journal of the British Astronomical Association*, 32, 223). Professor Douglass added that it seemed to him "a very important corroboration of the relationship between solar activity and terrestrial conditions, for I presume that these tree variations are related directly to the weather."

Sunspots, if looked at casually, appear to differ widely in their form and behavior, but a little systematic observation shows that, for the most part, they conform in their history to a single type. As an illustration we may take the group which attained its maximum development in March, 1920, and of which the Rev. A. L. Cortie has summarized the life history in the *Monthly Notices*, 80, 574-578, where it is accompanied by seven drawings of its appearance. This type is that of a more or less regular stream, of which the first and last spots are usually the largest, best defined, and the most stable. The straight line joining the two chief spots—sometimes distinguished as the “leader” and “trailer”—was in this case parallel to the sun’s equator.

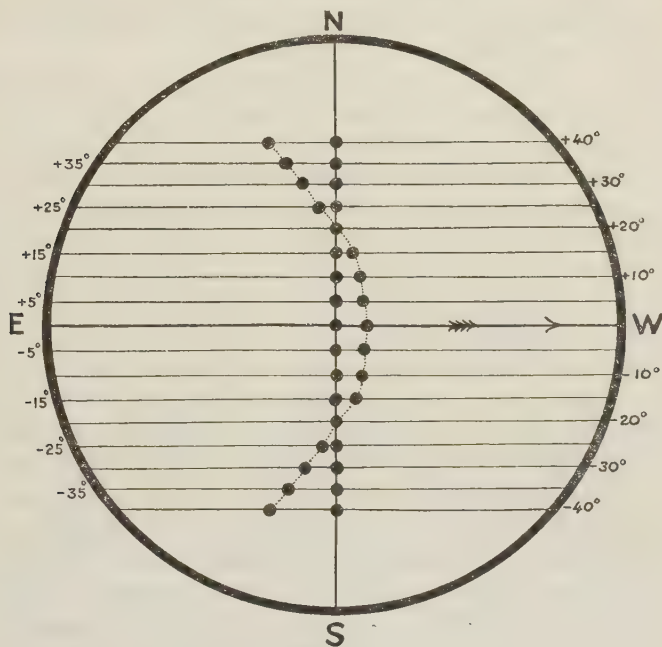
Professor Hale has shown that all spots contain magnetic fields, and that the strength of this field (up to a certain maximum) increases with the diameter of the spot; and that the polarities in any one cycle follow a definite law with respect to the position of the spot on the sun according as it is north or south of the equator. If the sign of the dominant charge remains always the same, then opposite polarities may be regarded as representing opposite directions of whirl. Now in streams in which the “leader” and the “trailer” are dominant, Professor Hale has pointed out that these two are of opposite polarities; that is, of opposite directions of whirl. Where, then, we have two “bipolar” streams, one north and one south of the solar equator, we find that the two leaders have whirls in directions opposite to each other, and, similarly, the two “trailers” have whirls opposite. Further, during the cycle ending in 1913, the leader spots in the northern and the trailer spots in the southern hemisphere were of negative polarity; the sign of the polarity being positive for the southern leaders and northern trailers. But during the cycle after 1914, these relative whirls were interchanged, the northern leaders and southern trailers becoming positive and the southern leaders and northern trailers negative, until June 24, 1922, when a small single spot (probably a leading spot whose trailer had become invisible) in north latitude 31° , was found to have south or negative polarity. This was the first indication that the new cycle just beginning was again experiencing a general reversal of polarities.

Thus during the minimum years of 1913-14 and of 1922-24, we have not only the high latitude spots of the new cycle overlapping the low latitude spots of the old, but also four spot zones, characterized by distinct magnetic polarities coexisting together. But the general magnetic field of the sun shows no reversal of polarity.

Professor Hale also points out (*Contributions from Mount Wilson Solar Observatory*, No. 165) that the inclination of the axis of the spot stream, which is in general represented by the line joining the

“leader” and the “trailer,” bears a definite relation to the latitude at which it occurs. The “trailer” tends to be further from the equator than the “leader,” and “in low latitudes the axes are nearly parallel to the sun’s equator; but with increasing latitude the mean inclination increases to a maximum of about 11° ” in the region of latitude 30° to 35° .

To go back in the history nearly 60 years, one of the most notable contributions to the answer to the question “What is a sun?” was supplied by the Redhill Observations of Sunspots made by R. C.



To illustrate the relative movements in longitude of Spots in different Solar latitudes in one rotation of the Sun.

FIG. 5

Carrington in the years 1853–1861, in which he redetermined the position of the sun’s axis and the rotation period of the sun. In particular, he showed that each different zone of latitude, north and south, has its own rotation period. The annexed diagram (fig. 5) will roughly illustrate the general effect. It is drawn on the assumption that there is a spot in every fifth degree of latitude, and that at a given moment these 17 spots were all observed to be on the central meridian of the sun’s apparent disk. If, then, each spot traveled westward with the *average* speed of apparent motion appropriate to its own particular latitude, then in $27\frac{1}{2}$ days the spots would be found in the positions indicated on the curved line.

Referring again to "the butterfly diagram," the shift of the habitat of spot groups during the progress of the solar cycle shown therein would appear to be a sort of surface ripple on the sun, moving in both hemispheres from high latitudes to low, as each cycle proceeds from its beginning to its close. The case of the Cepheid variables has made us familiar in recent years with the idea of stars which change their volume—stars with pulsating photospheres. In the sun we have, as yet, no proof of a *general* pulsation of the photosphere; only of this ripple of disturbance on its surface. But, since the rotation period, as indicated by sunspots, is shorter as the equator is approached, it follows that the mean rotation period of the sun is quicker before minimum than after.

But the above diagram puts the fact of the difference in the rotation periods of different latitudes in much too crude a form. A paper on "The solar rotation period from Greenwich sun-spot measures, 1879–1901," appeared in the Monthly Notices, 65, and on page 817 a table was given (Table II) which was intended to show how wide are the differences of rotation period, as derived from different spot groups even in the same latitude. Every group has a proper motion of its own; even within the same group there are internal movements. The leader spot in the early days of a group tends to rush forward over the surface; in the group's later history to slacken speed and return on its track.² Also the groups which live the longest, returning two or more times to the visible hemisphere of the sun, move more slowly on the whole than short-lived spots, and yield different rotation periods during their successive apparitions.

One remarkable peculiarity is common to both the cycles, 1879–1891 and 1891–1901, and since it was brought out by Carrington's inquiry two cycles earlier it is probable that it expresses a real peculiarity of the solar rotation. In spite of the great irregularity in the rotation periods given by the spots in any particular zone, there does appear to be a distinct tendency for the shortest mean period to be given, not at the equator, but slightly to the north of it. The curve given by the different rotation periods is not precisely symmetrical with respect to the equator, and, *on the whole*, there appears to be a tendency for the periods in the northern latitudes to lengthen more rapidly with distance from the equator than with those of the southern. A similar feature was suggested in "the butterfly diagram," wherein the southern hemisphere appeared to encroach slightly on the northern at the equator. The equator of rotation would appear not to coincide with the equator of figure, but to lie slightly to the north of it.³

² "Notes on some of the spot groups measured at the Royal Observatory, Greenwich, on photographs of the sun taken in the year 1915," Monthly Notices, 79, 451.

³ See a paper communicated to the British Astronomical Association on "Rotation periods of the sun as determined from flocculi and from sunspots" (Journal of the British Astronomical Association, 32, 104–107): "We thus infer a state of strain not only between the southern and northern solar hemispheres, but also between the higher and lower strata in those hemispheres"; p. 106.

The different rotation periods given by long-lived spot groups during their successive apparitions are illustrated in figure 6, which exhibits the distribution in longitude of all groups lasting through three or more successive rotations during the years 1891–1894. The recurrent groups north of the Equator are marked N, those south of it S. It may be assumed that the greater the depth below the surface of the place of origin of a given spot group, the greater will be the

Distribution of Spot-Groups of Long Duration in the Years 1891 to 1894
in Heliographic Longitude.

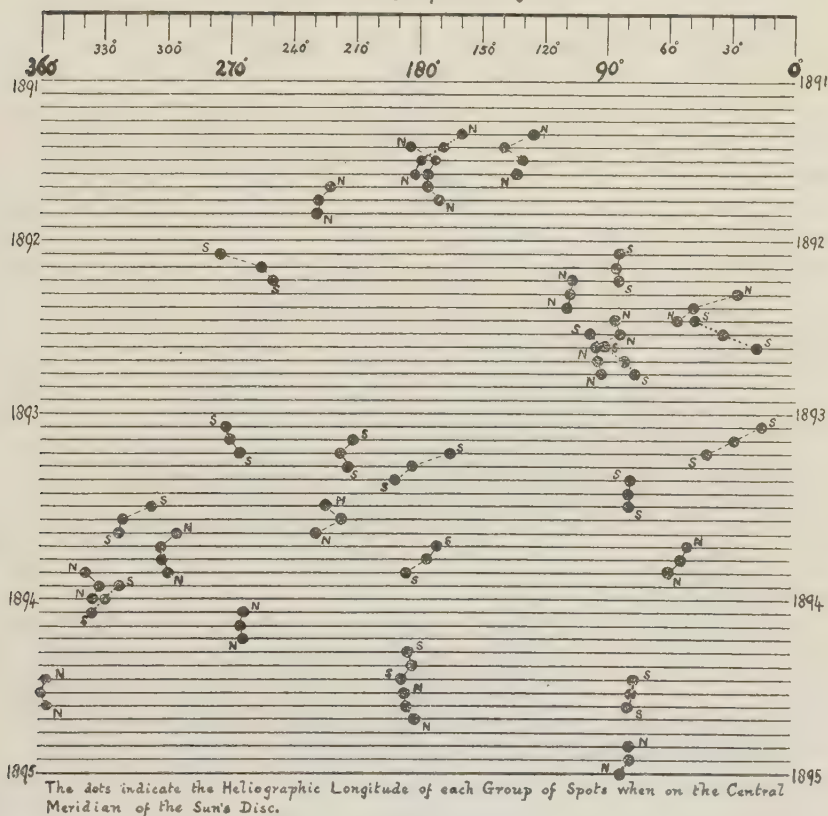


FIG. 6

difference of its observed rate of motion from the general surface drift.

The seventh diagram is drawn upon precisely the same scale as figure 6, and shows the distribution of certain solar longitudes. But these are not longitudes of spots on the sun, but of the center of the sun's disk at the moment when a magnetic storm began to be felt upon the earth. In this case every magnetic storm is recorded. It will be seen how similar is the character of the *associated* dots in the two figures; even though no spots are given in figure 6 that made only

one appearance. If the single appearances in figure 7 had been omitted, the resemblance between the two diagrams would have been much increased. In other words, the intervals between the successive returns of a group of spots to the center of the sun's disk, as seen from the earth, are strictly comparable with the intervals between the recurrences of a magnetic storm. Magnetic storms obey the law of the sun's rotation.

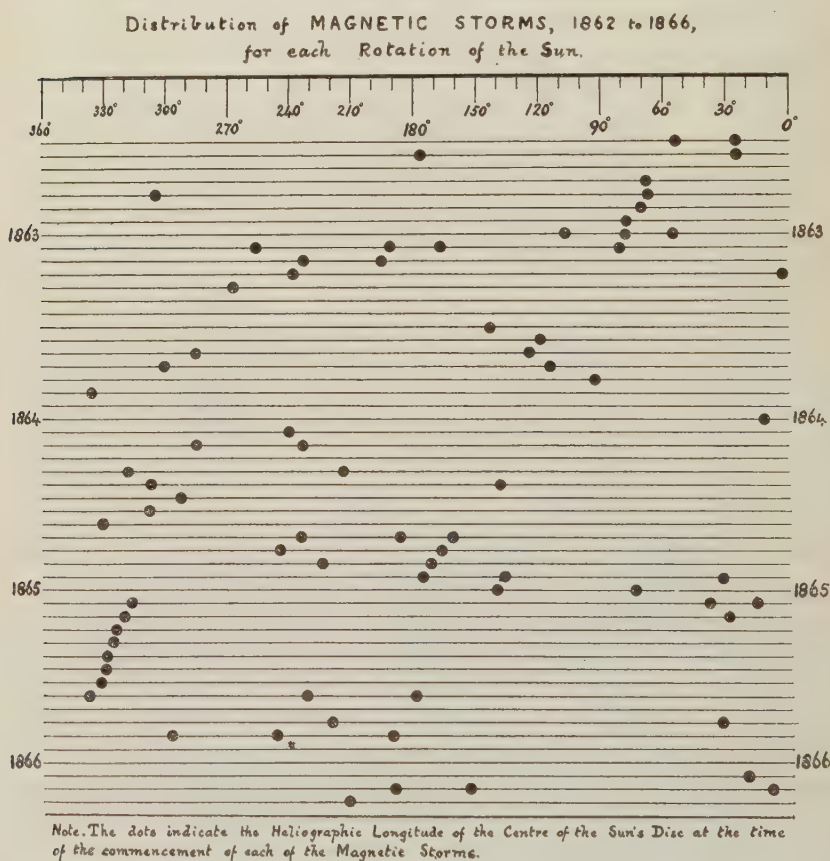


FIG. 7

This could not be so if the influence that brings about our magnetic storms proceeded equally from every part of the solar surface and was radiated from it equally in all directions. It follows that magnetic storms are brought about by an influence which arises from restricted areas of the sun's surface, and is discharged from such areas in restricted directions. Thus Mr. Gavin Burns has tabulated his records of auroræ (*Memoirs of the British Astronomical Association*, 23, Part I, "Report of the section for the observation of auroræ and the zodiacal light, 1916-1919") in recent years in accordance

with the solar rotation, and the tables show at a glance that the greatest displays synchronized with the return of certain special meridians to the center of the sun's disk; other meridians on the sun appear to leave our atmosphere quite undisturbed. The sun is structured, not only as between the northern and southern hemispheres, and as between different latitudes, but—as regards its emanations—as between some of its longitudes also.

There are such influences proceeding from the sun, and the outer corona is built up in obedience to them. This has been clearly seen in the photographs which have been secured of the corona on many occasions; as, for example, in the eclipse of December 12, 1871, photographed at Baikul by Lord Lindsay's assistant, Mr. Davis, and shown in the *Memoirs of the R. A. S.*, 41, Plates 7 and 8. The chief feature of the corona of this eclipse was the massing of its greater portion into petal-shaped formations, which were called at that time "synclinal groups." In Plate 7 the synclinal group in the south-southeast rises above a bright semicircular arc, and much fainter arches can be discerned rising above the lowest one. Above the highest of these the sides of the structure curve as if to meet; in Plate 8 they very nearly meet. Several similar synclinal groups were yet more distinctly shown in the photographs obtained by Sir W. H. M. Christie in the eclipse of 1898 at Sahdol in India, and again in the eclipse of 1901, by the members of the British expeditions to Sumatra and Mauritius.

But it was in the eclipse of 1898 that the structure of the outermost corona was photographed; and the synclinal groups, so beautifully shown on Sir W. H. M. Christie's negatives, were seen on photographs taken at Talni, with a Dallmeyer astigmatic lens of $1\frac{1}{2}$ inches aperture and 9 inches focus, to terminate in long narrow straight beams, the apex of the highest arch in each of the groups being, as it were, blown out, and driven away in a straight line into space. The longest beam was traced for at least 6,000,000 miles.*

From photographs taken in these and other eclipses, it would appear that over certain disturbed areas of the solar surface leaf-shaped structures are built up, from the apices of which matter seems to be driven away in long straight rod-like beams. Such beams, driven forth into space and continually replenished from beneath, would, if in the right direction, from time to time overtake the earth in its orbit, and strike it on the sunset arc. Remembering that in a hot gaseous body like the sun, electrified particles, both positively and negatively charged, must occur in great numbers, we can understand how the same disturbed area may be fed with particles of different sign, which, by their mutual attraction, give rise to the rod-like beams that issue from it. These cross the space that separates the earth from the sun, and reveal their arrival here by means of magnetic storms and auroræ.

* Knowledge, for May, 1898, pp. 107-109.

Thus it is evident that the disturbed state of the sun's surface affects the earth. But there is also some evidence that the earth appears to affect the sun's surface. This appears in a slight, but distinct, dissymmetry between the eastern and western halves of the apparent disk of the sun, with respect to three orders of solar phenomena: the numbers of prominences; the areas of faculæ; and the numbers and areas of spot groups. There is some evidence that the amount and the sign of this dissymmetry vary in the course of the solar cycle. A complete explanation is still to seek.⁵

These conclusions and suggestions have been derived, during the century of the history of this Society, from observations of the changes, real and apparent, of the areas of sunspots and of their distributions in longitude and latitude.

APPENDIX *

In the two years since the writing of the original paper, several expressions for the rotation period of the sun, varying with the latitude, have been found for faculæ and flocculi, phenomena which differ in character from sunspots and from each other. Comparing the zones, 5° in breadth, of greatest activity (those with their centers at $12\frac{1}{2}^\circ$ on either side of the Equator) for five of these investigations, we have the following result:

TABLE I

	Authority	Daily sidereal motion	Mean synodic rotation period
Spots observed from 6 to 14 days.....	Maunder.....	14.45	26.71
Faculæ.....	Newton.....	14.42	26.79
Flocculi.....	Fox.....	14.38	26.89
Recurrent spots	Maunder.....	14.34	26.95
Faculæ.....	Chevalier.....	14.33	26.98

It will be seen that the extreme difference from the mean is only 0.12 of a day.

But these are all mean values for the zone; the scattering shown by the individual objects in any zone is as marked and significant as is the crowding round the mean rotation period in that zone. For example, for spots observed from 6 to 14 days the most active zones have synodic periods ranging from $23^{\text{h}}4$ to $30^{\text{h}}0$ and faculæ and flocculi both show a scattering of about the same order.

⁵ Monthly Notices, 47, 451: "An apparent influence of the earth on the numbers and areas of sunspots in the cycle 1889-1901"; and Memoirs of the British Astronomical Association, 23, Part II, "Report of the section for the observation of the sun, 1910-1919"; "The distribution of faculæ between the four quadrants of the sun's apparent disk," p. 46.

* Added June 17, 1924.

This fact has a bearing on the rotation periods of the sun given by magnetic storms. It implies that it is not possible to determine with any degree of certainty the particular zone of solar latitude, from whence a pair of magnetic storms have arisen, merely by noticing the interval in time that has occurred between them. Thus Table II gives for 190 pairs of storms occurring between 1848 and 1913, and for spots from 1879 to 1901, the degrees of favor shown for the various synodic periods.

TABLE II

Synodic rotation period	Northern spots	Magnetic storms	Southern spots	All spots
d				
23.5	0	0	1	1
23.9	0	0	4	4
24.3	5	0	9	14
24.7	12	0	15	22
25.1	29	0	32	61
25.5	43	1	46	83
25.9	82	10	77	159
26.3	119	16	137	256
26.7	151	27	177	328
27.1	191	62	242	433
27.5	117	20	144	261
27.9	50	33	68	118
28.3	25	13	40	65
28.7	10	8	16	26
29.1	6	0	6	12
29.5	1	0	2	3

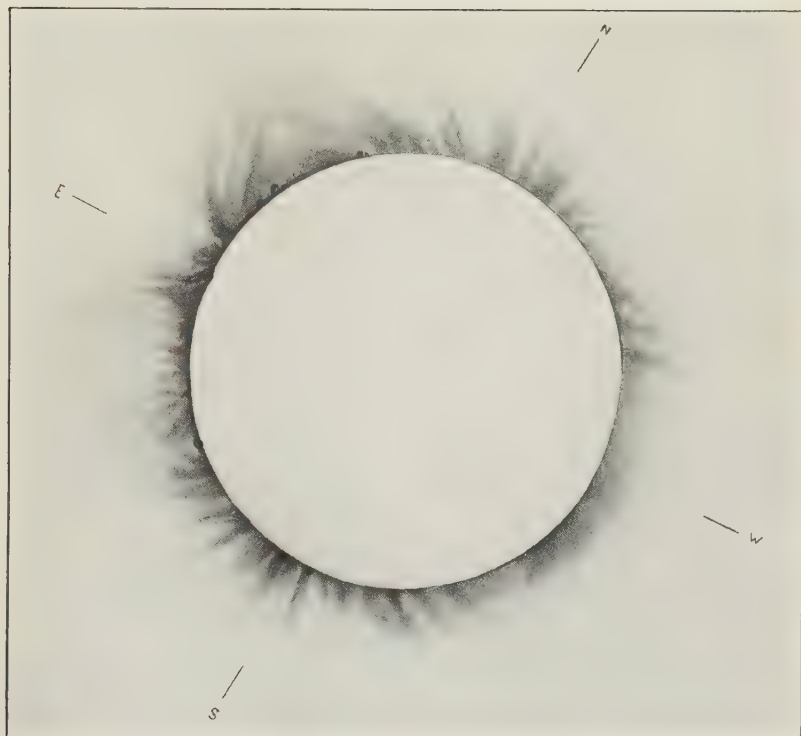
It is evident that both spots and magnetic storms concentrate sharply upon a synodic period of 27.1 days.

The representations of the corona, shown in Plates 1-7, are drawings made from photographs taken by Mrs. Maunder in 1898 in India, and in 1901 in Mauritius. A drawing of the former was made by the late Mr. W. H. Wesley; the drawings from the Mauritius eclipse were made by Miss Beatrice Handler. In the latter it will be seen that there are two leaflike formations, each covering a very disturbed arc of about 60° . In the complete corona of longer exposure, the apex of each leaf is shown, but while that of the more northern is prolonged radially out into a beam, the apex of the more southern is directed somewhat toward the equator, so that the beam as a whole is inclined to the normal. In the small-scale photograph, that taken in India in 1898, we see one of the beams prolonged into a straight rodlike ray; straight to as great a distance as it can be distinguished upon the photograph. A recent paper by Mr. E. A. Milne on "The average life of an excited calcium atom" (Monthly Notices, 84, March, 1924) gives some idea of the way in which such rays arise in the disturbed sun-spot zones and how their particles escape outward from the sun.

Lately, Doctor Abbot has shown that these rodlike rays, which are streams of particles, restricted as to the areas from whence they arise, and in the directions in which they are emitted, affect another planet of the solar system. In the Proceedings of the National Academy of Sciences for October, 1923, Doctor Abbot points out that "when sunspots transit across the central diameter of the visible disk, lower radiation values occur, and usually reach a minimum on the day following the transit," and to explain this, quotes the observations of Guthnick on the brightness of Saturn, which indicated certain small fluctuations. These fluctuations agreed in percentage with the variations of the solar constant, provided a time allowance was made to take account of the rotation of the sun from a position facing the earth to one facing Saturn. "It seemed, in short, as if rays of a certain intensity of radiation, going out from the sun, rotated along with it, and so affected the different planets in the order of their heliographic longitudes." He finds such ragged, unequal rays in the solar corona, and it is evident that this lower radiation, about a day after a spot transit over the central meridian, and a magnetic storm are both due—directly or indirectly—to the same rays, for in the cases of the magnetic storms, which accompanied the spots 9127 and 9143 (of the Greenwich series) in February and March, 1920, the lower solar constant in each case occurred about the time of greatest height of the magnetic storm. The latter is due to the disturbance of the earth's magnetism by the solar ray; the lower solar constant is attributed by Doctor Abbot, to the diminished transparency of the enveloping ray itself.

We therefore now recognize two distinct methods of radiation from the sun; the first, general, from the entire surface and in all directions; the second, special, arising from certain districts in certain zones, and emitted in restricted directions only.

Indications of variations in the general radiation have been found by Doctor Abbot by higher values of the solar constant here on earth, when sunspots form, or are increasing, or are brought by the solar rotation into view at the east limb of the sun, and whenever the solar surface is shown by the $H\alpha$ spectroheliograms to be much disturbed. "When a period of quiescence in solar activity occurs, the radiation values tend to fall continually until some new outbreak of activity is observed." An agreement has also been established between the rate of the melting of the white polar caps of Mars and the progress of the solar cycle. Thus, in 1916 (Monthly Notices, 76, No. 8), E. M. Antoniadi recorded that "out of 21 cases of observed melting of the caps between 1862 and 1914, inclusive, there are four more or less unfavorable and seventeen favorable to the agreement in question."

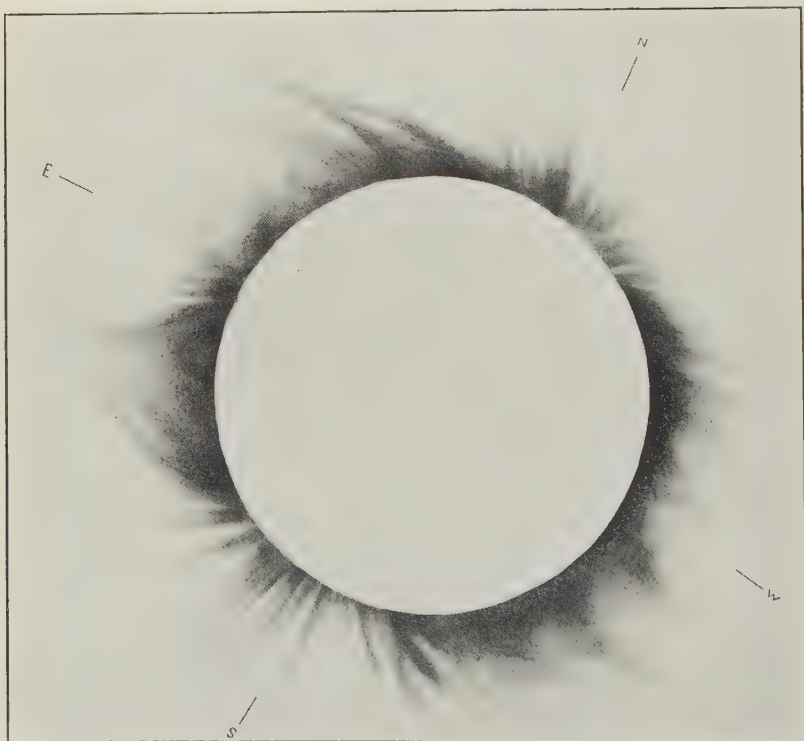


THE CORONA OF 1901, MAY 18

Mrs. Walter Maunder's expedition to Mauritius. (Long. 3h. 50m. 12.6s. E.; Lat. 20° 6' S.)

Drawing by Miss Beatrice Handler from a photograph taken 7 seconds after the commencement of totality, with the "Newbegin" telescope of 4¼ inches aperture, and 71 inches focal length. Exposure ¼ second. Plate, Lumiere, "Series A."

The letters N. S., E. W., indicate approximately the direction in which the sun's axis and equator, respectively, lie.



THE CORONA OF 1901, MAY 18

Mrs. Walter Maunder's expedition to Mauritius. (Long. 3h. 50m. 12.6s. E.; Lat. 20° 6' S.)

Drawing by Miss Beatrice Handler from a photograph taken 144 seconds after the commencement of totality, with the "Newbegin" telescope of $4\frac{1}{4}$ inches aperture, and 71 inches focal length. Exposure 8 seconds. Plate, Imperial, "Fine Grain Ordinary." The letters NS., E. W., indicate approximately the direction in which the sun's axis and equator, respectively, lie.



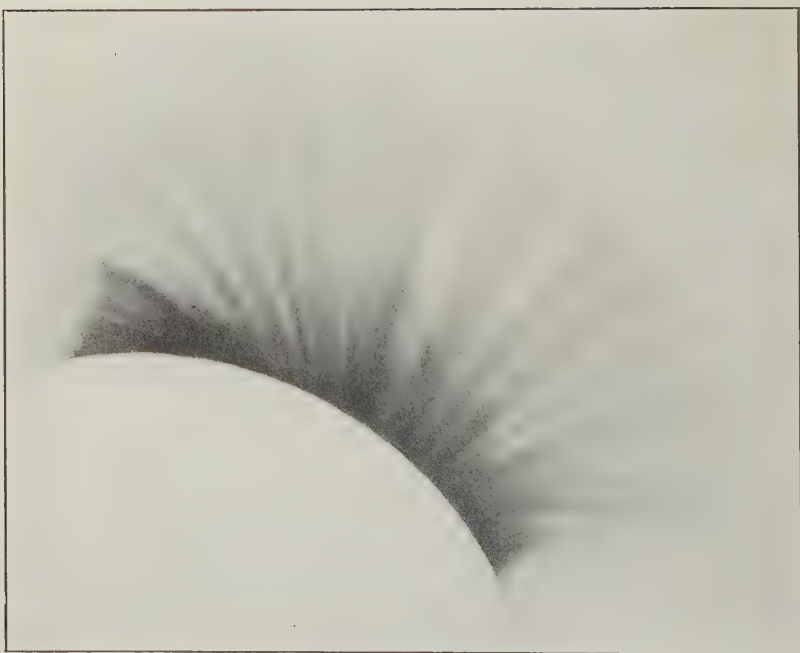
DISTURBED EASTERN LIMB



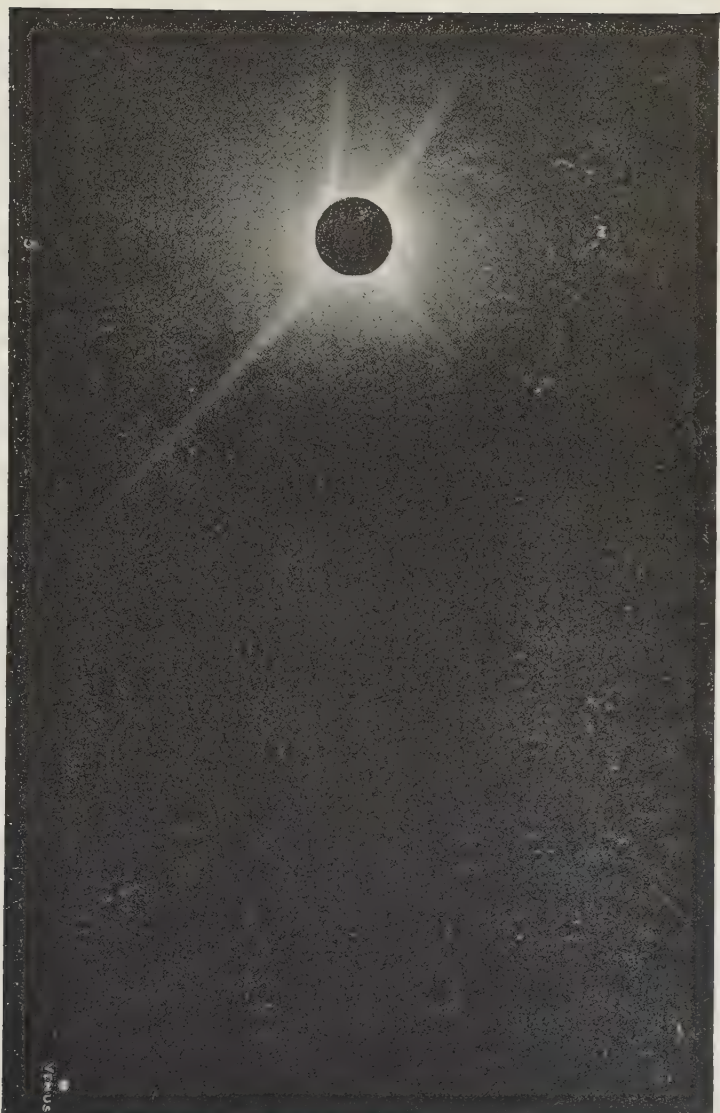
SOUTH POLAR "PLUMES"



NORTH-EAST SYNCLINAL WING



NORTH POLAR "PLUMES"



DRAWING BY W. H. WESLEY OF THE 1898 ECLIPSE

Published in Knowledge, May, 1898

JOINING THE ELECTRIC WAVE AND HEAT WAVE SPECTRA

By E. F. NICHOLS and J. D. TEAR

[With 2 plates]

HISTORICAL

There are few if any more fascinating chapters in the history of science than those dealing with the development of our present theory of light and the growth of our knowledge gained by careful experiment upon which any acceptable theory must rest. For centuries there was strife among "natural philosophers" as to whether light was due to countless myriads of minute imponderable particles called corpuscles, shot out along straight lines in every direction from the source of light, or whether light was an orderly wave motion spreading out equally and radially in all directions in a universal imponderable medium called the ether.

Some of the most recent fundamental discoveries in radiation and the newer conceptions of atomic structure and discreet energy quanta to which these discoveries have given rise have raised new questions concerning some of the hard and fast details of the established wave theory with the likelihood that a partial compromise between these two age-old hypotheses may sooner or later develop. Many physicists are already prepared for a wave disturbance theory of light not quite so harmonious and simply geometric as the smoothly and evenly spreading wave front nor yet so crudely material and projectilelike as the older corpuscular theory. Much more, however, must be known and done before a new agreement covering all details can be arrived at.

Historically, Young's discovery of the interference of two beams of light, made in the first year of the last century, was a decisive experiment in favor of a wave theory as opposed to a corpuscular theory, and it would doubtless promptly have convinced all physicists had it not been for the very great authority of Sir Isaac Newton which had come down through more than a century. Newton in his day had vacillated between a wave theory which had recently been quite elaborately worked out by the Dutch philosopher Huy-

gens, on the one hand, and the older and more widely favored corpuscular theory, on the other. Finally Newton definitely adopted the corpuscular theory of light, but still thought that heat radiation might be due to a wave motion. Newton was beyond question one of the greatest and most progressive thinkers of all time and, had he been alive, would have been among the first to recognize the convincing evidence of Young's experiment, but Newton dead proved a most formidable obstacle to progress.

Young not only proved the wave theory but actually measured the wave lengths of different colored light and showed a progressive increase in wave length as we go from violet through blue, green, and yellow to the extreme red. Thus the wave length of yellow light situated about midway in the orderly spaced band of colors which we call the normal spectrum is approximately 0.00059 mm. or one fifty-thousandth of an inch. From this time on to the middle of the nineteenth century, increasing and more convincing evidence of the wave theory slowly accumulated until Foucault actually measured the velocity of light in water and found it less than in air by an amount in exact accordance with the requirements of the wave theory, while the corpuscular theory required just the reverse; i. e., a greater velocity in water than in air. Thus a wave disturbance theory was finally established.

Fifteen years later Maxwell proposed a new theory of the nature of light waves which he based on Faraday's experiments. Maxwell's theory at the time it was proposed proved as abstruse and baffling for physicists of his day as we find Einstein's generalized theory of relativity in ours. In fact, Maxwell was the Einstein of his generation, and he succeeded in puzzling everybody. Maxwell's theory asserts that light is an electric wave disturbance in the ether caused by astoundingly rapid oscillations of minute electric charges in the source of light. But nobody then knew anything about rapidly oscillating electric charges in light sources, and another outstanding difficulty in believing that light waves were electric waves was that nobody had discovered any electric waves with which to compare them, nor was there any clearly recognized indication that electric waves were possible.

In the following decade the Berlin Academy of Sciences became interested in Maxwell's theory and offered a prize to anyone who would give experimental proof of its fundamental assumption. Not long after this prize was offered, von Helmholtz called the attention of one of his most promising students to it. That student was Heinrich Hertz, who later not only obtained electric waves some 2 feet long in the laboratory but went further and performed a number of experiments demonstrating that these waves, like light, were reflected

from surfaces, bent from their course by prisms, and that they traveled through space with the velocity of light.

Hertz's successors worked in two different directions. Righi, the Italian, and a number of other physicists worked toward shorter and shorter electric waves and repeated with them more and more of the classical experiments with light. Sir Oliver Lodge, Guglielmo Marconi, a brilliant young Italian experimenter, Branly, Fleming, and Braun were inspired by the idea of making electric waves a means of signaling and communication. These men, working individually, pushed toward longer and longer waves, because long electric waves carry farther and are not so easily scattered by obstacles as short ones. As we know, Marconi won in the contest of perfecting a practical means of communication without wires, and from his success we now have radiotelegraphy, and with the advent of the vacuum tube amplifier we have the greater marvel of radiotelephony. Thus Hertz worked indefatigably to discover electric waves in order to prove that Maxwell was right in maintaining that light waves were electric waves. Hertz's discovery, with its consequences, is but one of an accumulating number of instances in which astoundingly practical results have followed directly from the most abstruse workings of the scientific imagination.

Contemporaneously with the discovery and development of electric waves, great progress was also being made in the investigation of light and heat waves. Explorers were pushing out into the dark spectrum below the longest visible red waves. Among the earlier of these pioneers, and the most brilliant and successful one, was our illustrious countryman, Prof. S. P. Langley, who began his researches in 1883, using his newly perfected bolometer. He extended the known spectrum and accurately measured wave lengths down to 5.3μ , nearly 10 times the length of yellow light waves. By his researches he not only determined the distribution of energy in the solar radiation but laid experimental foundations for the development of our present general laws of radiation. A decade later a new method for sifting out and isolating certain long wave radiations from the total output of hot bodies, such as a candle flame or a Welsbach gas mantle, was discovered by Rubens and Nichols. This method led to an extension of our knowledge of long wave lengths and their measurement to waves more than 25 times the longest actually measured by Langley. Another twofold extension was accomplished by a further advance in method due to Rubens and Wood, and finally, in 1911, heat waves 0.324 mm., or one seventy-fifth of an inch, in length, were successfully isolated, measured, and their properties studied.

There was, however, still an unbridged gulf between the shortest known electric waves and the longest measured heat waves, for the

followers of Hertz and Righi had been stopped in their progress toward short waves about 1 cm., or two-fifths of an inch, in length.

In some experiments still in progress at the Nela Research Laboratory of the National Lamp Works, at Cleveland, the writers, by devising new and improved instruments and methods of experimentation, have succeeded in generating and working with electric waves as short as 0.220 mm., or one one-hundredth of an inch—waves considerably shorter than Ruben's and von Baeyer's 0.324 mm., heat waves.

DESCRIPTION OF SENDING AND RECEIVING APPARATUS

The arrangement of apparatus used in the new experiments is shown in Plate 1. The Hertzian oscillator or sender is contained in a brass box, O. The oscillator is a point source, and the diverging pencil of electric wave radiation emerging from it is formed into a parallel beam by a lens of paraffin wax. At R_2 , with a similar lens in front of it, is a check receiver. Waves emitted by the sender first fall on the reflecting screen, G, which is usually of ebonite, and are partially reflected into the check receiver. The remaining portion passes through the screen and falls upon the reflecting echelon analyzer, a flight of exactly equal brass steps, S. From the face of the echelon, the beam of electric waves is reflected to the main receiver, R_1 . A motor-driven vacuum pump for exhausting the two receivers is seen in the background. The check receiver, R_2 , serves simply as a control on the intensity of the beam emitted by the oscillator, so that any erratic changes of intensity of the emitted radiation may be recognized and corrected for.

The oscillator.—In a sectional diagram of the oscillator or sending apparatus shown in Figure 1, in which interior parts appear very much magnified, B is a brass case containing kerosene. T_1 and T_2 are glass tubes in which very small cylinders of tungsten, H_1 and H_2 , are sealed. These tungsten cylinders, separated by a short spark gap in kerosene, form the Hertzian doublet which emits the short wave radiation. High potential leads, V_1 and V_2 , from an induction coil charge H_1 and H_2 by leakage across air gaps, G_1 and G_2 , until H_1 and H_2 build up a sufficiently high potential difference to break down the kerosene insulation in the spark gap, G. The ensuing electrical oscillations between H_1 and H_2 are the source of the electric waves. Radiation emerging from the oscillator case passes through the thin circular mica window, W, falls on the paraffin lens, P, and is formed into a parallel beam. M is a concave metal mirror behind the doublet to reenforce the issuing beam by reflecting the backward emission of the oscillator. For simplicity many necessary details, such as fine adjustments for regulating the spark gap, etc.,

are omitted from the diagram. The wave lengths sent out by the oscillator depend on the length and diameter of the tungsten cylinders, H_1 and H_2 . For the shortest waves generated, these cylinders were 0.1 mm. long by 0.1 mm. diameter (0.004 by 0.004 in.). In use these small tungsten cylinders are rapidly worn away by the spark. For single observations, therefore, the oscillator was in most instances operated for periods of less than half a second.

The receiver.—The type of electric wave receiver employed was a newly designed modification of the Nichols radiometer, which makes use of the curious temperature effect in rarified gases dis-

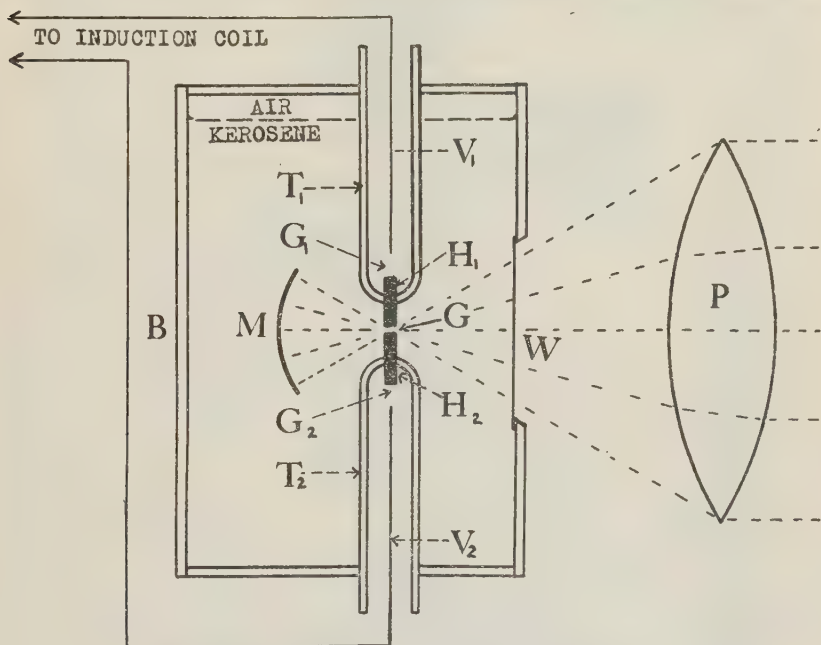


FIG. 1.—Schematic sketch of Hertzian oscillator unit

covered 50 years ago by Sir William Crookes. He found that if a thin plate, warmer on one face than on the other, is mounted in an inclosure from which the air has been pumped out until only about 0.0015 part remains, the residual gas exerts a very slight excess pressure on the warmer side of the plate. To illustrate this effect, Crookes designed the little radiometers or light mills often seen revolving in optician's windows.

To utilize this effect in a very sensitive electric wave receiver, the instrument shown in the cross-sectional diagram, Figure 2, was constructed. A greatly enlarged diagram of the suspended receiver system is shown at A. D is a very thin whip of drawn glass bearing two similar cross arms, EE. To these are attached two very

thin, narrow, mica strips, V_1 , V_2 . Immediately in front of V_1 and directly behind V_2 are mounted still narrower mica strips, P , coated with very thin deposits of metallic platinum. When electric waves fall on metal conductors, they cause very small oscillatory currents in the surface layer of the metal. Such thin metal coatings as P possess high electrical resistance. Hence these oscillatory currents generate minute quantities of heat, which in these experi-

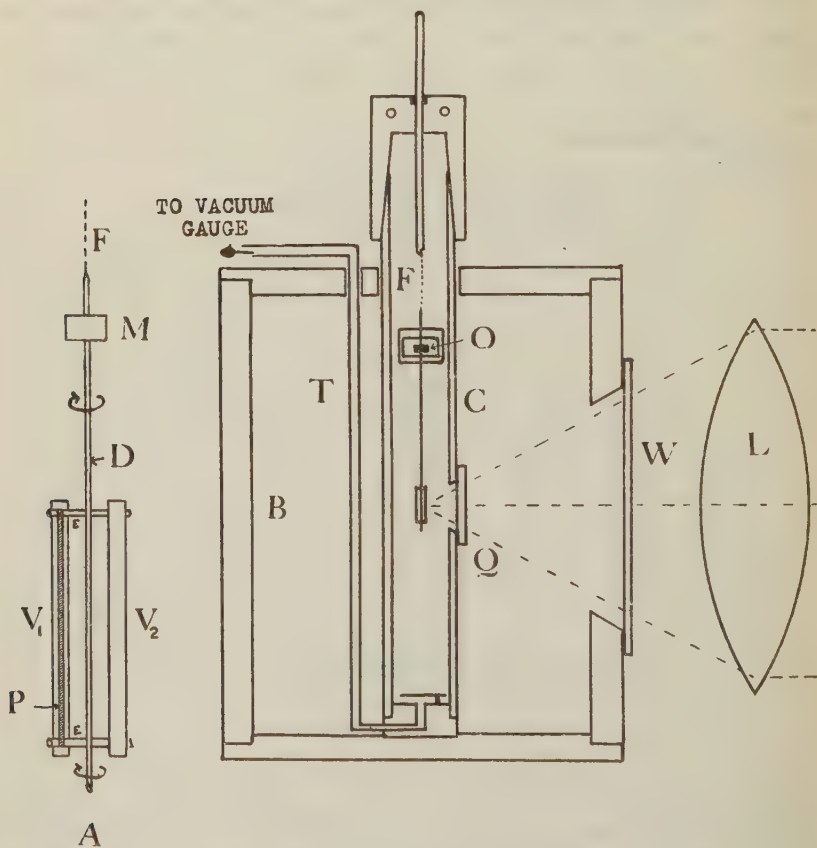
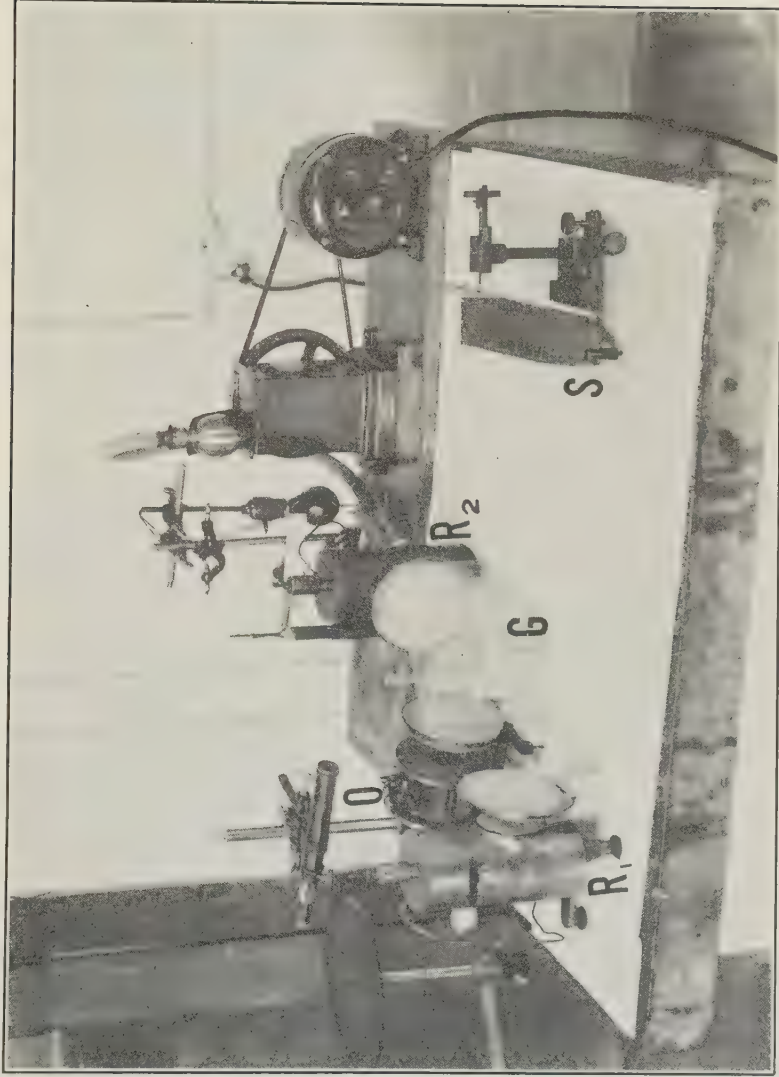
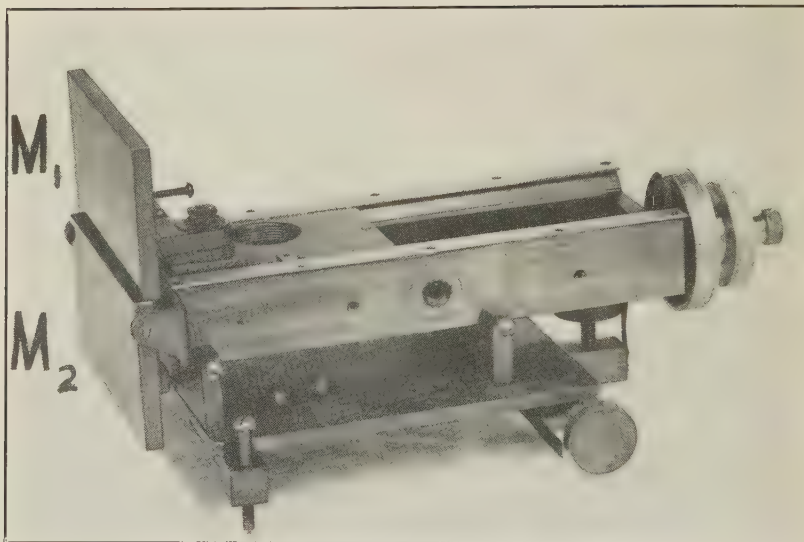


FIG. 2.—Sketch of electric wave receiver

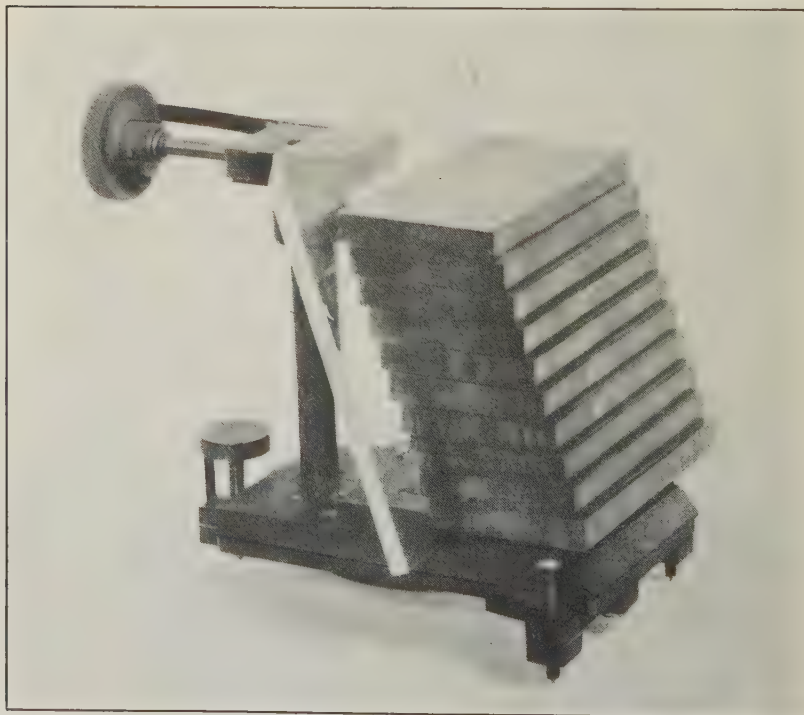
ments raise the temperature of P by amounts roughly of the order of one-millionth of a degree. The resulting increased gas pressure on the warmed metal sides of the vanes V_1 and V_2 tend to rotate the system in the direction shown by the arrows. The suspension also carries a very thin glass silvered mirror, M , by which the amount of the rotation of the system can be accurately measured. This suspension complete weighing usually less than 1 mg. (about one-thirty thousandth part of the weight of a 2-cent letter) is hung on a very fine fiber of spun quartz, F , from a central stem in the double-



PHOTOGRAPH OF SHORT ELECTRIC WAVE APPARATUS



1. THE BOLTZMANN MIRROR INTERFEROMETER



2. PHOTOGRAPH OF REFLECTING ECHELON

walled brass case C and B. From the inner case, C, the air can be exhausted through the tube T. This case has two window openings, one covered by the quartz plate, Q, admitting the electric waves, and the other, O, through which the rotation of the suspension can be measured, covered by glass. The outer protecting case, B, has corresponding openings, and the beam of the electric waves is focused on the vanes, V_1 and V_2 , of the suspension by the paraffin lens L. The forces due to the resistance heating of the electric

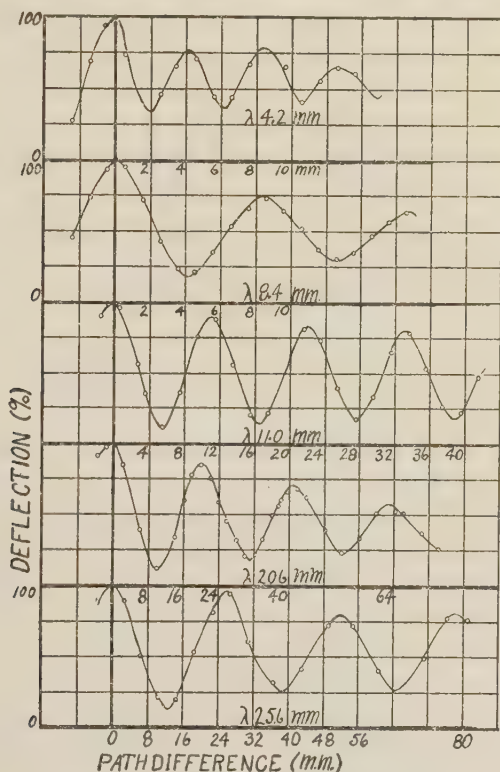


FIG. 3.—Interference curves taken with the Boltzmann mirrors

waves which rotate the suspension are opposed by the resulting twist of the quartz fiber F. The angle of twist of the fiber under proper conditions is found to be proportional to the intensity of the electric wave radiation, and thus quantitative measurements of wave intensity are easily made.

Wave-length measurements.—Wave-length measurements of the radiation received from the electric oscillator were made with two types of analyzers. The first, shown in Plate 2, Figure 1, is the interferometer, due to Boltzmann, consisting of two parallel mirrors, M_1 and M_2 , of which M_1 can be displaced backward or forward with-

out rotation. When M_1 is slightly behind M_2 , as shown, a wave train reflected from the upper mirror has a longer path to follow from sender to receiver than the other half of the same train reflected by the lower mirror. It is thus delayed, and when the two halves of the beam are reunited at the receiver, the separated wave trains may no longer match. By varying the distance by which the plane of the mirror M_1 is behind that of the mirror M_2 , wave crests in one beam can be made to fall on the earlier wave crests of the other, and thus

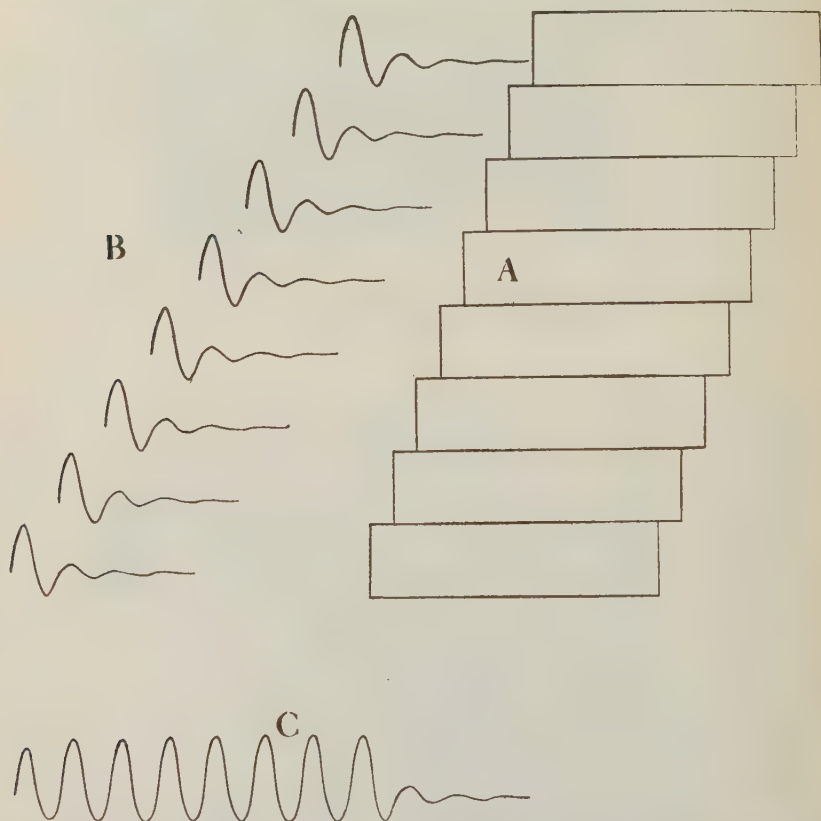


FIG. 4.—Sketch illustrating the formation of a relatively long wave train from a short electromagnetic pulse

the two beams reenforce each other. On the other hand, wave crests of one can be brought together with the wave troughs of the other, and the two made to weaken each other. Observed positions of the mirror M_1 for reenforcements and neutralizations thus give a direct means for measuring the wave length of the radiation.

When oscillator and receiver are strictly in tune, interference curves like those shown in Figure 3 are obtained. In these wave diagrams, vertical distances from 0 to 100 represent radiant intensities as shown by the receiver. Horizontal distances to the right

indicate differences in the length of path of the two beams reflected by the two mirrors M_1, M_2 . This path difference equals twice the displacement of the movable mirror.

A more complete knowledge of the form of wave trains sent out by the oscillator is obtained by the newly designed reflecting echelon analyzer shown in Plate 2, Figure 2. This instrument is in the form of a staircase made of 10 exactly equal brass blocks, the lower back edges of which rest against a slanting plate of glass. The tilt of this glass plate and consequently the width of tread of the steps can be controlled and measured by the micrometer screw seen at the top of the apparatus. The way a single wave from the oscillator is divided up after reflection from the rises of the steps is shown diagrammatically in Figure 4, B. A shows the outline of the steps and C is the wave form obtained when the short individual wave trains are brought together again at the receiver. By varying the width of the steps, this instrument gives a complete analysis of the wave trains, showing both wave length and form.

The simplicity of the principles involved in these experiments and the homely character of the apparatus used may easily conceal the almost vanishing smallness of the quantities measured and the great experimental difficulties which had to be overcome.

The extended electric wave spectrum.—With the instruments and methods indicated we have not only artificially manufactured and measured electric waves 220μ (one one-hundredth inch) long but have used our electric wave receiver in two different forms to detect and remeasure the 324μ (one seventy-fifth inch) heat waves obtained from hot bodies. Thus, for the first time, waves from hot bodies and artificially generated electric waves of the same length have been obtained, compared, and found identical in character. These experiments thus supply the last link in a long chain of experimental evidence connecting light with electric waves and furnish a final proof of Maxwell's electromagnetic theory of light.

That not only radiation emitted by highly heated bodies, including infra-red, visible, and ultra-violet rays are electric waves, but so also are X ray and gamma rays from radium, can no longer be questioned. Thus the true electric wave spectrum is expanded by an enormous extent, for a 20,000-meter radio wave is over 20,000,000 billion times as long as a short gamma or X ray.

Of many things thus brought to notice, nothing is more surprising than the very narrow limitations of the eye in perceiving electric waves as light. Our entire range of vision from the farthest violet to the deepest red is only from a wave length of about 0.39μ to 0.78μ . It is not possible to show such small detail and such vast extent as is embodied in the electric wave spectrum by any chart

laid out in simple proportion, for if we represent the length of the visible spectrum by one-quarter inch space, then the whole ultra-

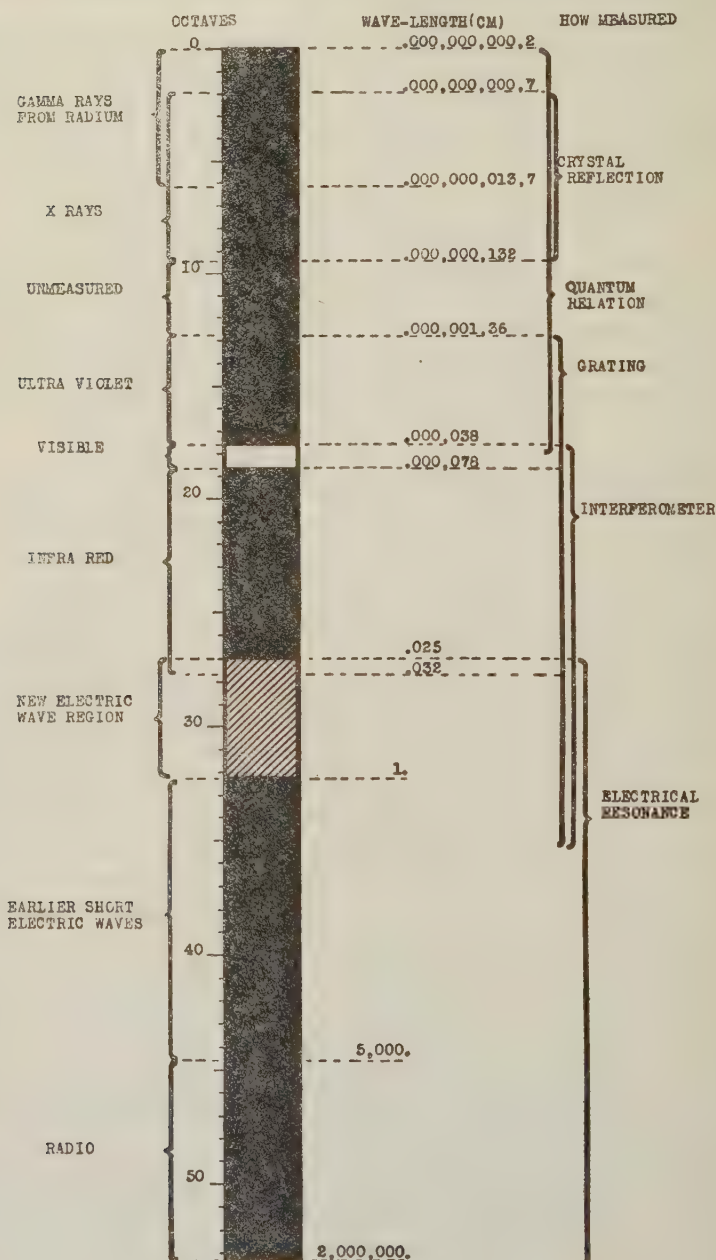


Fig. 5.—Chart of the electromagnetic spectrum

violet, X ray, and gamma ray spectra are crowded into another one-quarter inch at the left, while on the right the infra-red spectrum

reaches out to the longer electric waves which extend to long radio waves which lie at a distance on our scale of a 100,000 miles to the right—surely an unwieldy chart!

A more convenient and adequate method of charting the whole sweep of this comprehensive spectrum is by using geometric intervals such as the ascending powers of 2 used in laying off a piano keyboard, on which the wave length of two notes an octave apart are to each other as 2 to 1. Such a spectrum chart is shown in Figure 5. On the left are the usual names given to the division of the spectrum. These names are historical in character and belong to the time when the identity of the spectrum as a whole was not realized. To these historic divisions, braces are attached to show approximately their extent on the black strip representing the spectrum. Beyond is shown the number of octaves embraced in each division, and farthest to the right the wave lengths roughly corresponding to these regional boundaries. Of the 53 octaves of the spectrum shown in Figure 8, only 1 octave contains wave lengths visible to the eye, and there is but one remaining region of 3.3 octaves between the ultra-violet and X ray spectra in which actual wave-length measurements have not been made. Waves lying in this interval and also radiations beyond the shortest measured X rays and gamma rays indicated have been observed, and the recently discovered "quantum" relationships give a sound theoretical basis for calculating these wave lengths, but no interference or diffraction measurements have thus far been carried out in these limited regions.

Matter under the action of heat is capable of giving off radiations in the so-called infra-red, visible, and ultra-violet spectra; gamma rays are the natural accompaniment of radioactive transformations, and there are various static electric phenomena in the atmosphere which give rise to disturbances resembling fragments of very long electric waves, but X rays and the old and new short electric waves we may still regard as artificial or purely products of laboratory manufacture.



THE POSSIBILITIES OF INSTRUMENTAL DEVELOPMENT¹

By GEORGE E. HALE

Nothing is more encouraging to the scientific investigator than the rapid multiplication in recent years of the possibilities of instrumental development. In astronomy the opportunities for advance have been vastly enlarged by the remarkable progress of physics and chemistry, and the many new instruments and methods thus rendered available. To appreciate our advantages, we have only to glance rapidly over the history of science and contrast present possibilities with those of the past.

The beginning of the new year, practically coinciding with the annual inundation of the Nile, was fixed by observations of the heliacal rising of Sirius before 4000 B. C. Throughout their entire history the Egyptian priests were astronomers, yet their sundials, water clocks, and the crude "Merkhet," a measuring instrument for determining the time from observations of stars near the meridian, apparently underwent no important improvement down to the Greek occupation of Egypt. The Babylonians, although much more effective observers than the Egyptians, have left us no instruments, unless the "astrolabe" found in the palace of Assurbanipal may be thus classed. The Greeks invented several instruments, which are described by Ptolemy in the *Almagest*. Most of these consist essentially of a graduated arc of a circle, provided with adjustable sights and supported in the plane of observation. So completely did these instruments embody the ingenuity of the Greeks that they were adopted without important change by the Arabs, Hindus, and Chinese, and served for the equipment of Tycho Brahe's great observatory in the period of revival of the sixteenth century. Tycho devoted special attention to the improvement of instruments, which he constructed in his own shops. But though spectacles had been worn since the end of the thirteenth century, he little suspected the great opportunity they placed within his grasp.

The history of lenses is full of interest. It is very improbable that the disk of rock crystal, oval in shape and roughly ground to a plano-

¹ Reprinted by permission from *Popular Astronomy*, Vol. XXXI, No. 9, November, 1923.

convex form, which was found by Layard in Sargon's palace at Nimroud, was actually intended for use as a lens, in spite of Sir David Brewster's contrary opinion. Nor can it be safely affirmed from their minuteness of detail and perfection of execution that the finely engraved gems of antiquity were cut under lenses. Pliny the elder and others state that globes filled with water were used as burning glasses, and Seneca remarks that "letters though small and indistinct are seen enlarged and more distinct through a globe of glass filled with water." Yet while defects of vision were frequently discussed by many classic authors, they made no reference to the simplest optical aids, and myopia was repeatedly declared to be incurable down to the end of the thirteenth century, when spectacles first came into use.

Roger Bacon and his teacher, Grossteste, undoubtedly understood some of the properties of lenses and concave mirrors, but the evidence advanced to support the opinion that Bacon used telescopes for astronomical observations is not convincing. The early history of the telescope remains rather obscure, but from our point of view the most important fact is its application in astronomy by Galileo and the revolution in human thought effected by his discoveries. His sudden recognition and utilization of a principle which had certainly been applied in the case of spectacles for 300 years quickly transformed the equipment of the observatory and laid the foundation of astrophysical research. In 1630 Francesco Generini saw the feasibility of using the telescope for increased precision in pointing, presumably by introducing threads into the focal plane of the eyepiece. About 10 years later the inventor of the micrometer undoubtedly used this method. The modern period of astronomical measurement was thus begun.

As for the telescope itself, it was first improved by the invention of the Keplerian eyepiece and then increased in focal length to overcome the troublesome effects of aberration. Rayleigh has shown that a single lens of 1.7-inch aperture is as good as an achromatic when its focus is 66 feet. Huygens, who worked out the theory of aberration, consequently greatly increased the aperture and focal length of his telescopes. He also devised the Huygenian eyepiece and was rewarded for his efforts by the discovery of the true nature of the rings of Saturn. Three of his objectives, with focal lengths of 122, 170, and 210 feet, respectively, are still in the possession of the Royal Society. Telescopes up to 600 feet in length were made in this period, but the difficulty of finding and following the celestial object seriously affected their value. Obviously, they could not be carried on equatorial mountings, first described for telescopic purposes in Scheiner's *Rosa Ursina*, but really not different in principle from the equatorial armilla of Tycho Brahe. An accessory of the highest

importance developed at this time was the pendulum clock, devised by Huygens following Galileo's discovery of isochronism.

Two steps taken for the purpose of overcoming chromatic aberration ultimately proved successful. The reflecting telescope, introduced by Gregory and Newton, reached apertures of 4 feet in the hands of Herschel and 6 feet in those of Lord Rosse. The invention of the achromatic objective, followed by the production of optical glass in larger and larger disks, made way for the great refractors of the present day. Their high perfection, like that of the modern reflector, is the result of successive advances in the art of the glass maker, the metallurgist, the mechanical engineer, and the optician, and the development of modern machine tools, which Lord Rosse did not possess. Even if the photographic plate had then been perfected, the absence of an accurately driven equatorial mounting would have rendered it useless with his 6-foot reflector. The refinement and precision of the modern meridian circle, with its nearly perfect pivots and beautifully graduated circles, is another result of the improved art of the instrument maker, which is also illustrated in such valuable accessories as the latest types of clocks, the recording chronograph, and the moving wire micrometer.

The first telescopes collected about 80 times as much light as the unaided eye, and this light-gathering power has now been increased to about 200,000 times that of the eye. As the quality of the atmosphere and the optical and mechanical perfection of the best modern instruments are sufficiently good to permit all of this light (barring losses by reflection) to be concentrated and held in a very small image, the gain thus effected is enormous. But the advantages derived from the introduction and improvement of the photographic plate, and the development of many auxiliary instruments and methods, are still more important.

When Newton decomposed sunlight with a prism in 1672, he took the first great step in the initiation of spectroscopy. It was not until 1803, however, that Wollaston, using a narrow slit instead of Newton's wider one, detected the principal dark lines in the solar spectrum, nearly 600 of which were measured by Fraunhofer in 1814. Their interpretation by Stokes, who, in 1852, recognized that the double D line is due to sodium vapor, which absorbs the same radiations that it emits, and later by Kirchhoff and Bunsen, who, in 1859, identified many terrestrial elements in the sun, provided the means of determining the chemical composition of celestial objects.

The study of stellar evolution, foreshadowed by Herschel and by Laplace in the nebular hypothesis, was thus rendered possible in the very year of the publication of Darwin's *Origin of Species*. This was a tremendous advance, even when only the classification of stellar spectra, at once undertaken by Secchi and Huggins, and

the apparent variation of chemical composition with stellar evolutionary progress, are considered. But the chief significance of the adoption of the spectroscope in the observatory lies in the extraordinary versatility of this instrument, and the possibilities it affords of utilizing in astronomy the widest variety of physical and chemical discoveries.

In 1842 Doppler tried to prove that the color of a star depends upon its velocity. If a star radiated monochromatic light and its velocity were great enough, his conclusion would be correct. Rightly applied with the spectroscope, his principle has given us the means of measuring the motions of gases in the solar atmosphere; the rotation of the sun, planets, and nebulae; the orbital velocity of close double stars discoverable only by this method; and the velocity in the line of sight of various celestial objects.

I wish that time permitted me to dwell on the extraordinary harvest which has resulted from the skillful application of this and other principles of physics, but I can only recall a few of them. The shift toward red or violet of spectral lines by pressure affords a means of measuring the pressure in stellar atmospheres, after other effects have been allowed for. The variation of the relative intensities of lines with temperature gives one clue to stellar temperatures, and has also led indirectly to Adams' beautiful method of deriving absolute magnitudes and parallaxes from stellar spectra. Reduced to a sound scientific basis through the recent advances of physics, the study of line intensities has also become one of our most powerful guides, not only to the nature of stars but to the structure of the atom itself. The shift of the maximum of intensity in the spectrum as a function of the temperature, the influence of magnetic and electric fields on radiation, the phenomena of polarization, of anomalous dispersion, and of optical resonance are also among the numerous discoveries of the physicist which the astronomer has already utilized, with important positive or negative results.

In addition to the spectroscope, the astronomer has derived from the physical laboratory a long line of other valuable instruments. The photometer, now powerfully supplemented and largely displaced by photographic methods, has given us the magnitudes of tens of thousands of stars. The thermopile, bolometer, and radiometer have led to remarkable advances in our knowledge of the infra-red spectrum, the precise measurement of the varying intensity of the solar radiation, the determination of the heat radiation of stars as faint as the thirteenth magnitude, and even to studies of the energy spectra of some of the brighter stars. The photo-electric cell has yielded stellar photometric measures of surprising precision. The radiometer, which gave the first actual measure of the pressure of radiation, now known to play such a dominant part in the massive

stars, has recently provided the means of detecting the last wave lengths missing in the long range from the gamma rays of radium to radio waves 20,000 meters in length. The interferometer, springing from Young's famous interference experiment of more than a century ago, has served for scores of brilliant successes, recently culminating in the determination of the angular diameters of giant stars.

Without attempting to enumerate more of the astronomer's long list of debts to the physicist and chemist, let us look for a moment at the increase in the precision of measurement effected by instrumental advances. The star places of the Greek were given to the nearest 10' of arc, one-third the diameter of the moon. Tycho succeeded in reducing the probable error of a single measure of the distance between two neighboring stars to 57". In double star observations the probable errors of the best micrometric measures are about 0''.1. In modern photographic parallax determinations the probable error is about 0''.005 to 0''.010. With the interferometer, the probable error of a single measure of the separation of the components of Capella is 0''.001. The diameter of Arcturus, 0''.019, can be similarly measured with a probable error of about the same amount.

The advantages to be gained by the early utilization of the rapid progress of the physicist and chemist are obvious. Almost any discovery may help us directly or indirectly. We are interested in new organic dyes because they may improve the sensitiveness of our plates in various regions, especially in the infra-red, a most promising field for future research. We earnestly hope for a reduction in the size of the grain of the most rapid photographic plates, which would be equivalent to a marked increase in the aperture of our telescopes. We keenly watch for the appearance of new alloys, perhaps suitable for telescope mirrors or for the special needs of optical gratings; progress in the manufacture of optical glass; the production of large masses of clear fused quartz for prisms or mirrors—every technical advance, in fact, that we can learn to utilize. And we are equally anxious to benefit by the constant improvement of high-tension transformers, electric furnaces, vacuum tubes, electromagnets, and the many other devices on which we depend for the imitation and interpretation of celestial phenomena.

These illustrations of the increasing possibilities of instrumental development have not been enumerated in strict chronological sequence, but a glance at this partial list will show how rapidly the opportunities of the astronomer have multiplied in recent years. Another point should be noted: The obvious chance is not always the most important one, and the greatest advances may come from the recognition of possibilities that are not immediately apparent. Hence the astronomer can not watch too intently the progress of related sciences, and especially the numerous devices and methods

which are constantly arising in various fields. Such beautiful new instruments as the X-ray spectrograph or the mass spectrograph of Aston, while perhaps not directly applicable in astronomy, may contain hints, and also yield results, which can be used to advantage.

The above considerations will help to explain the somewhat unorthodox equipment and policy of the Mount Wilson Observatory. We have tried from the outset, with the valuable cooperation of our research associates, to at least utilize the more obvious possibilities offered by the progress of physics and chemistry, and to gain such advantages as laboratory conditions and methods placed at our disposal. Hence the design of the Snow and tower telescopes, equipped for solar research; the *coudé* principle and constant temperature laboratories of the 60-inch and 100-inch reflectors, arranged for the photography of stellar spectra under high dispersion, and for investigations like those with the thermopile, bolometer, and radiometer on stellar radiation and energy spectra; the exceptional care taken to secure smooth rotation of the 100-inch dome in order to diminish the vibration of the high dispersion stellar spectrograph (soon to be mounted on its pier) during exposures continued for several nights; the construction of the ruling machine, one of the prime purposes of which is to permit such experiments as have just rendered possible the concentration of most of the incident light in any desired order of spectrum; the development of the stellar interferometer, first in conjunction with the 100-inch telescope and now as a separate instrument. Hence the provision of machine and optical shops adequate for a wide range of constructional work and a physical laboratory in which to conduct researches required for the interpretation of celestial phenomena. Hence also our close cooperation with the California Institute of Technology, the recent growth of which as a research institution is so advantageous to the observatory.

Looking ahead, and speculating on the possibilities of future instruments, it may be mentioned that comparative tests of the 60-inch and 100-inch telescopes promise well for larger apertures. Their practicability, so far as this depends upon atmospheric limitations, can be fairly well tested by observations of the united star images given by the two mirrors of a stellar interferometer at increasing separations. The production of large mirror disks is another problem. Fused quartz mirrors, if they can be made of sufficient dimensions, will be extremely valuable for solar telescopes and large reflectors because of their low coefficient of expansion, but for moderate apertures pyrex glass has already proved a fairly effective substitute. As for the stellar interferometer, I believe it will ultimately attain apertures of 100 feet or more, possibly in some fixed form,

with accurately controlled coelostats. Fixed telescopes and spectrographs for solar work, whether horizontal or vertical, can be shortened if desirable by the use of telephoto lenses or by combinations of mirrors. Both the ultra-violet and the less refrangible part of solar and stellar spectra deserve more consideration than they have received, and here especially improvements in the photographic process, as well as in prisms and reflecting surfaces for the ultra-violet, are greatly to be desired. No increase in the resolving power of the grating is required for astronomical purposes, but more light, obtainable from greater area of ruled surface, with concentration in a single order, is still needed for various researches.

I shall not attempt in this paper to deal with less obvious possibilities, or to discuss particular problems. Let me conclude with the reminder that if instruments are important, "the man at the eye end" is more important by far. In the Hindu treatise *Siddhanta Siromani*, the astronomer Bhaskara, after describing a new form of instrument, exclaims: "But what does a man of genius want with instruments, about which numerous works have treated? Let him only take a staff in his hand and look at any object along it, casting his eye from its end to the top, there is nothing of which he will not then tell its altitude, dimensions, etc." If we can not afford the sacrifice of precision which is here so lightly recommended, we may at least remember that the mathematician embodies in himself the most powerful of all instruments for the solution of celestial problems, and we may also find encouragement in the simple means that have served in many classical researches. When Young laid the foundations of the wave theory of light, and discovered the principle of the interferometer, his instruments were limited to a small mirror, a few bits of paper and cardboard, some fine hairs, and a couple of knife blades. If we are not mathematicians or experimental physicists, and do not share in the use of large telescopes, we may still find ample encouragement in the history of astronomical progress. We have only to recall the splendid results obtained by systematic observation with small telescopes by such men as Burnham, Barnard, and Carrington, or those derived, also with small instruments, by men like Huggins, Secchi, and the pioneers in astronomical photography, from the prompt and intelligent application of methods and devices borrowed from the laboratory.

THE BORDERLAND OF ASTRONOMY AND GEOLOGY¹

By Prof. A. S. EDDINGTON, F.R.S.

The region in which geology and astronomy most conspicuously overlap is in the theories of the origin of our planet. We have, in fact, two main theories—one due originally to an astronomer, Laplace, and the other to a geologist, Chamberlin.

In the last century the evolution of a star seems often to have been regarded as something quite detached from the evolution of the stellar universe. Just as the birth and death of a man is an incident which can occur at any time in the rise and decline of the human race, so it was thought that the birth and extinction of a particular star formed merely a detached incident in the course of progress of the stellar universe—if, indeed, the universe was progressing in any particular direction. Thus it was a natural belief that the stars died out and were re-formed by collisions of extinct stars; and that the matter which now forms the sun had undergone many alternations of incandescence and extinction since things first began. But this view is quite at variance with the general tendency of sidereal astronomy in the present century. We have come to recognize that the stellar system is one great organization, and that the stars which are shining now are more or less coeval with one another. Everyone would admit that Mars and Jupiter were formed as parts of one process of evolution—not necessarily at the same moment, but each formed as the process reached the appropriate stage; and similarly we now believe that it was one process of evolution sweeping across the primordial matter which caused it to form itself into stars; and these original stars are the actual stars which we see shining now. No doubt the evolution did not develop at the same rate in all parts of the universe, and there are probably places where stars are still being formed; but you will see that this view is entirely different from the other view that stars were being formed individually by haphazard collisions of dark stars, so that each was an independent formation, having no time connection with other stars.

This view has been forced on us partly by direct evidence of organization among the stars, pointing to a common origin for large groups of stars. We notice scattered groups such as the Hyades, which have almost exactly equal and parallel motions.

¹ A lecture delivered before the Geological Society of London on November 21, 1922. Reprinted by permission from *Nature*, January 6, 1923.

Clearly it would be impossible to form such a group if each star were the product of an accidental collision. The only way in which a common motion like this can arise is by associated development from some nebula or other diffuse distribution of matter. The connection is clearly a connection of common origin. Again, practically all the bright stars of Orion form a similar group, having common motion; and, moreover, they have all reached a similar stage of evolution. They are connected with the great Orion nebula, the faint extensions of which fill up nearly the whole constellation. It is obvious that here we have to deal with a single evolutionary development. But another point which militates against a collision theory is the extreme rarity of collisions and close approaches. The distances separating the stars are enormous compared with their own dimensions. Sir Frank Dyson once used the illustration of 20 tennis balls, distributed at random throughout the whole interior of the earth, to give a model of the density of distribution of the stars. It has sometimes been objected that we do not know how many extinct stars may be wandering about and colliding. Dyson's 20 tennis balls represent only the *luminous* stars; there may, for all we know, be millions of *dark* bodies ready to be fired into incandescence by collision. I think, however, that there is now good evidence, based on the dynamics of stellar motions, that the dark stars can not greatly outnumber the luminous stars—probably not ten times and certainly not a hundred times. (If they were more numerous than that, the average velocities of stars would, owing to the gravitational attraction, be much higher than is observed.) That argument, then, is no longer valid. Taking a very liberal view of the kind of approach that can be held to constitute a collision it is estimated that a star would only suffer collision once in 10^{14} years.

Thus the astronomer is not predisposed to look favorably on a hypothesis of the origin of the solar system which postulates anything of the nature of a collision. He has the conception of an orderly development of the stars crystallizing out of the primordial material, and, unless perhaps in exceptional cases, following an undisturbed course of development. We hope for a theory that will show us the star after its first isolation from surrounding material spontaneously developing the system of planets.

It now appears almost certain that, whether the original matter was gaseous or whether it was composed of meteors, it must at an early stage in the star's history have been completely volatilized into gas. This was while the star was extremely diffuse, and, for example, before the planets separated from it. This means that the material now forming a planet has at one time passed through the furnace, and has cooled down from a gaseous stage. How far

that has a direct bearing on geology I can not say, since I have nothing to guide me as to the course of its subsequent checkered history. I do not say that the earth was a gaseous body when it first became recognizable as an independent planet, but I am convinced that its material was at one time merged in a completely gaseous sun.

It may be of interest to indicate why it seems so probable that a star in its early diffuse state is gaseous and not meteoric. The stars are known to be of closely similar mass. There are occasional exceptions, but probably 90 per cent of them are between one-half and five times the sun's mass. We have no explanation of this uniformity if they are initially merely aggregations of solid meteors; but we have a very exact explanation if they are gaseous. In fact this critical mass round which the actual masses of the stars cluster so closely is predicted by the theory of equilibrium of spheres of gas, using only well-known physical constants determined in the laboratory. The crucial factor is radiation pressure, which is inappreciable in smaller masses, and almost suddenly takes control between one-half and five times the sun's mass. There can be little doubt that large radiation pressure, tending to overcome gravity, conduces to instability, so that larger masses have small chance of survival. Somewhere about one-half the sun's mass the radiation pressure no longer counts seriously, so that there is no tendency for the primitive material to break into smaller units.

The existence of radioactive minerals on the earth seems to supply another reason for believing that its material was originally subjected to high temperature or to physical conditions of a different order from those now prevailing. In radioactivity we see a mechanism running down which must at some time have been wound up. Without entering into any details, it would seem clear that the winding-up process must have occurred under physical conditions vastly different from those in which we now observe only a running down. The only possible guess seems to be that the winding-up is part of the general brewing of material which occurs under the intense heat in the interior of the stars.

The trend of this argument has been against the Chamberlin-Moulton hypothesis, and in favor of some form of nebular origin of the solar system. It is, of course, accepted that the details of the original nebular hypothesis of Laplace require modification. Also the word nebula is meant to signify diffuse gaseous material in general, and has no immediate connection with those objects which we see in the sky, and call *nebulæ* more particularly. There is still controversy as to what process of evolution is represented by the spiral *nebulæ* which are seen in such numbers—what they will ultimately turn into; but the controversy is whether the spiral

nebula will give rise to a cluster of a few hundred stars, or whether it will turn into a stellar universe on the same scale as the great system of some thousands of millions of stars which forms our galactic system. There is now no suggestion that it has anything to do with the formation of so insignificant a system as the solar system. But in preferring the nebular hypothesis to that of Chamberlin and Moulton, it is necessary to make a certain reservation. We have hitherto taken it for granted that the formation of a system of planets is a normal feature of the evolution of a star. Most of my arguments have referred to the development of stars in general, and would become irrelevant if it could be admitted that the solar system were an exceptional formation violating ordinary expectation.

We know that at least a third of the stars are double stars, and I do not think there is any reason to think that planetary systems would be formed when the evolution takes that course; but until recently it was taken for granted that the remaining single stars would generally (or at least frequently) be the rulers of systems of planets. Jeans has recently pitched a bombshell into the camp, suggesting that the solar system is a freak system—the result of a rare accident, which could only happen to one star out of a very large number. He found no way of accounting for it as a normal process. I have not the specialist knowledge necessary to criticize the details of the working of the nebular or of the planetismal theory of development, but before regarding Jeans' argument as conclusive (he himself makes reservations) I should be more satisfied if the effect of radiation pressure had been taken into account. It is fairly clear that radiation pressure plays a great part in the separation of nebulous matter into stars, and although I have no definite reason to think that it can account for the separation of planets from the sun, I do not feel satisfied that we have got at the whole truth until that point has been duly examined.

Supposing, however, that we are forced to accept Jeans' suggestion that the solar system is a freak system, some of my objections to the Chamberlin-Moulton hypothesis are removed. I can not admit that the conditions of collision which that hypothesis requires are normal features in the formation of stars; but they might have happened occasionally in the history of the universe, and produced the solar system, the sun being thus an exceptional star born out of due time. But if my arguments against Chamberlin's hypothesis fall to the ground, there are probably other astronomers prepared to attack it in other directions.

The new views as to the age of the earth are now pretty well known to geologists. I may sum them up briefly in the statement that Lord Kelvin's estimate of the extent of geological time need not now be taken any more seriously than Archbishop Ussher's, and

that the geologist may claim anything up to 10,000 million years without provoking a murmur from astronomers. Although there may still be some difficulties about the exact source from which the vast heat energy the stars pour out into space is derived, it is now clear that the Helmholtz contraction theory is inadequate to give the necessary supply. The astronomer has no such precise means of measuring geological time as the physicist has now discovered by the analysis of radioactive minerals; but he can add his contributory evidence that the sun, and presumably therefore the earth, is much older than Lord Kelvin allowed. In the Cepheid variable stars it seems possible to measure the actual rate at which evolution is proceeding—the rate at which the star is condensing from a diffused state to a denser state. The star is believed to be pulsating, and as it expands and contracts the light varies in quantity and character. In a pulsating gravitating mass the period is proportional to the inverse square root of the density, so that by observing the rate at which the period is changing we can deduce the rate at which the density is changing. I may add that the law that the period depends on the inverse square root of the density is very closely confirmed by comparing the values for the various Cepheids. In this way we find that for the best observed of these stars, δ Cephei, the density is changing 500 times slower than the contraction hypothesis assumes. It would, of course, be risky to assume that the same proportion holds at all stages of the evolution of a star; but it suggests that Lord Kelvin's estimate of 20 million years for the age of the sun might well be multiplied by 500 to give 10,000 million years. At any rate, the Cepheid observations show that the stars must have some other source of energy besides contraction.

I suppose it must be a matter of interest to geologists whether the intensity of the sun's heat has been constant or whether it was at one time hotter than now. I think we can say fairly definitely that the sun was formerly much hotter.² There must have been a time when the sun's heat was from 20 to 50 times more intense than it is now. That would no doubt have made a great difference to many geological processes. Unfortunately, I can not say whether it occurred in known geological epochs. It must have occurred after the earth had begun to exist as a separate planet; but whether it was before or after the sequence of geological strata began to be laid down I have no idea. It would not be unreasonable, however, to expect that in the early geological times the sun was several times hotter than it is at present.

After the evolution of the solar system, we naturally turn to consider the evolution of the earth-moon system. My impression is that

² New facts have emerged since this was written. I think we can now say "fairly definitely" that the sun's heat has not altered appreciably during the last 10,000 million years. (November, 1924.)

nothing in recent progress suggests any doubt that the beautiful theory of Sir George Darwin is substantially correct. The main features are that the moon at one time formed part of the earth, and broke away. At that time the rotation period of the earth was between 3 and 4 hours, and the cause of the fracture was that the solar tidal force synchronized with a free period of natural vibration of the earth; owing to resonance the tidal deformation of the earth continually increased until rupture occurred. The earth's period of rotation has since lengthened to 24 hours, owing to frictional dissipation of energy by lunar and solar tides; and the back reaction of the lunar tides on the moon has caused the moon to recede to its present considerable distance. All this has well stood the test of searching criticism, and must be considered as extremely probable. Modern research has added two contributions; it enables us to calculate the magnitude of this tidal friction at the present time, and it enables us to locate more exactly the region where the frictional dissipation is occurring.

I believe it was Darwin's view that the tides most potent in wasting energy were not water tides but tides in the solid earth; that is to say, we have to do with deformations of the whole earth under the tide-raising force of the moon's attraction. Undoubtedly these deformations of the earth occur, but everything turns on whether the process of deformation is attended with serious friction. H. Jeffreys has pointed out that the phenomenon of latitude variation is accompanied by similar deformations of the earth; and in this case it is clear that the friction is inconsiderable, for otherwise the deviations of the pole from the symmetrical position would be damped out almost at once. It seems, therefore, very unlikely that the solid tides can have had much effect in the process of tidal evolution of the earth-moon system. Ocean tides are likewise of small effect, as Darwin himself had seen. The modern conclusion is a very curious one; it is in the landlocked shallow seas that nearly all the mischief occurs. This was discovered by G. I. Taylor, who found that the Irish Sea alone is responsible for one-fiftieth of the whole amount required by observation. The remaining landlocked basins on the earth are probably capable of making up the necessary total.

The actual rate at which the earth's rotation is being slowed down at the present era can probably be deduced with fair accuracy from the records of ancient eclipses. The day is lengthening about one-thousandth of a second per century or 1 minute in 6,000,000 years. At this rate we should have to go back more than 10,000 million years to the time when the day was between 3 and 4 hours and the moon was born. Since the rate depends on the accidental circumstance of occurrence of shallow seas, no definite prediction can be made; but allowing for the much greater effect of the tides when the moon was nearer to us, it is difficult to date the birth later than 1,000 million years ago.

Had the earth a solid crust at the time the catalysm happened? I cannot tell at all. But, if it suits geological theories, I can see no objection whatever to the hypothesis that the earth had a solid crust at the time. No cohesion of the crust would seriously resist the enormous forces involved when the resonant vibration got started. It would not be appreciably more difficult than the disruption of a molten earth. The view that the Pacific Ocean is the hollow left at the place where the moon broke off seems tenable unless geologists find objection to it; and in that case we may suppose that the water now collected in the hollow formerly covered the earth—or most of it. This change of condition of the earth may (or may not) have happened within geological times. When the earth was covered with water there would be no landlocked seas and no appreciable tidal friction from the sun (the moon being not yet born), so that we can allow a long previous history during which the length of day was nearly constant at 3 or 4 hours. That rather helps to make the whole theory self-consistent.

These speculations stand very much as they did when Darwin put forward his theory. But I am tempted to add further speculations arising out of the location of the frictional dissipation. (I am taking advantage of the great opportunity for speculation which this address affords. Ordinarily I am restrained, because people would ask, What facts can you produce in support of your speculations? But here I am asking the question, Have you any facts which seem to support them? If not, by all means let them drop.) The frictional dissipation acts as a brake on the earth's rotation, and we now feel confident that the brake is a surface brake applied at certain points on the earth's surface where the favorable conditions exist. The retarding force is transmitted to the earth's interior, and so delays the rotation as a whole; but unless the material is entirely nonplastic there will be a tendency for the outer layers to slip on the inner layers. I do not know how much the material a few hundred miles below the surface would be expected to give under the strain; it may be inappreciable, but I will assume that though small it has some effect.

We have then the whole crust slipping from east to west over the main part of the interior. Probably it would go very stickily, sometimes arrested by a jamming which would hinder it for a time and then going on more easily. That is helpful in explaining certain astronomical observations. There are irregularities in the motions of heavenly bodies, noticed particularly in the swift moving moon, but shown also on a smaller scale in the sun and planets, which appear to indicate that our standard timekeeper, the earth, is a little irregular. Now, of course, it is the rotation of the *surface* of the earth which determines our standard time. I find it difficult to believe that there can be irregular variations in the angular

velocity of the earth as a whole; but it seems less difficult if the variations are merely superficial, due to the crust sliding non-uniformly on the interior. I have even entertained the wild idea that the motion of the magnetic poles might be due to this cause; the magnetism being constant in the interior but with the axis emerging at changing points of the crust as the crust slips over the inner magnet. Unfortunately, so little seems to be known about the motion of the magnetic poles that I have not even been able to make out whether the motion is from west to east, as this theory definitely requires.

What interests the geologist more nearly is that the brake is applied only at certain areas on the surface, so that there would be a tendency to crumple the crust more particularly to the west of these areas.³ It is unfortunate that shallow seas are necessarily the least permanent features of the earth; otherwise I would have asked whether the geologists had evidence of special crumpling in such areas.

I have regarded the crust as fairly mobile from east to west. I suppose the geologists would also like it mobile from north to south in order to have glacial periods in those portions which are now near the Equator. It is not possible to hold out much encouragement for such an idea, because we can not imagine any force acting from north to south. Still if the crust, which is being urged by the east-west force of tidal friction, is resisted by obstacles it may be deflected, finding that, say, a southwest track offers less resistance. In a long enough time almost any displacement may have happened, granting my hypothesis that the connection of the crust to the interior is reasonably plastic. So I can not forbid this possible interpretation of glacial periods in the earlier geological times.

I am sure that it will not be supposed that, in presenting the astronomical side of these questions which belong both to geology and astronomy, I have any intention of laying down the law. The time has gone by when the physicist prescribed dictatorially what theories the geologist might be permitted to consider. You have your own clues to follow out to elucidate these problems, and your clues may be better than ours for leading toward the truth. We both recognize that we are adventuring in regions of extreme uncertainty where future discoveries will probably lead to various modifications of ideas. Where, as in the new views of the age of the earth, physics, biology, geology, astronomy, all seem to be leading in the same direction, and producing evidence for a greatly extended time scale, we may feel more confidence that a permanent advance is being made. Where our clues seem to be opposed, it is not for one of us to dictate to the other, but to accept with thankfulness the warning from a neighboring science that all may not be so certain and straightforward as our own one-sided view seemed to indicate.

³ I am not sure whether I am right in assuming here that the frictional brake is applied at the same points of the earth's surface where the dissipation of energy occurs.

ATMOSPHERIC NITROGEN FIXATION¹

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[With 4 plates]

The three essential food constituents of living matter are carbohydrates, fats, and proteins; the two former chiefly for the production and storage of energy and the latter for building up the body substance. They are alike in the respect that they all contain the three elements carbon, hydrogen, and oxygen, but differ in that protein also contains nitrogen, which, therefore, becomes one of the indispensable substances of life.

Nitrogen is a colorless, tasteless, and odorless gas, slightly lighter than air. It comprises about four-fifths of the volume of the atmosphere, where it occurs in a free state mechanically mixed with oxygen. In this free state, it is an exceedingly inert element and combines only with difficulty with certain other elements as will be explained later. In combined form, it is found chiefly in certain natural nitrate deposits, and natural manures such as guano also contain large quantities of nitrogen compounds.

FREE NITROGEN

The atmosphere is the inexhaustible source for our nitrogen supply, and every bit of nitrogen in plants, animals, and the soil has originated from free atmospheric nitrogen. Arrhenius estimates that no less than 400,000,000 tons of nitrogen are annually withdrawn from the atmosphere; and as nitrogen does not accumulate to any great extent in the soil, this enormous quantity must again be set free as inert nitrogen gas by the decomposition of organic matter and restored to the atmosphere. An immense and endless circulation of nitrogen is therefore continually going on, as shown in the accompanying diagram.

¹ Reprinted by permission from the General Electric Review for March and April, 1923.

Through the action of electrical discharges of thunderstorms, which continually go on in the atmosphere, appreciable amounts of free nitrogen in the air are converted into oxides of nitrogen which are absorbed by falling rain water and enter the soil in the form of nitric acid. This nitric acid then combines with the bases in the soil, such as potassium, calcium, etc., and forms the corresponding nitrates in which form they are taken up by the plants and metabolized into protein.

Through the action of bacteria in their root nodules, certain legumes, such as peas, beans, and clover, also possess the capacity of directly absorbing free nitrogen from the air during their growth and converting it into protein.

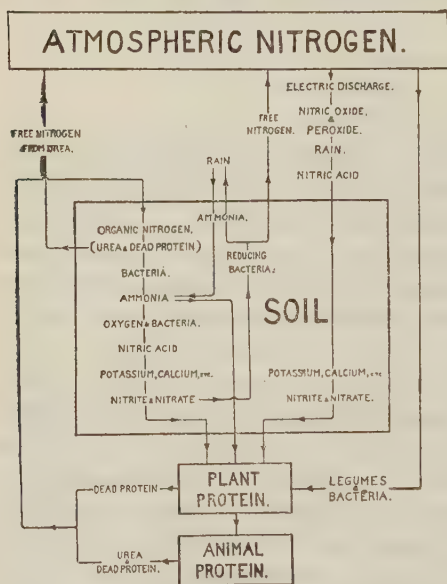


FIG. 1.—Elementary diagram of nature's nitrogen cycle

It has thus been shown how the nitrogen is supplied to the plants and protein metabolized which serves not only as their own food supply but also as reserve food for the plants' offspring. This now becomes animal food and, for vegetable eating animals, it is the sole source of the nitrogen for animal protein.

Part of the nitrogen which is not used for maintaining the body substance of animals is eliminated as urea and hippuric acid, and from

the urea much nitrogen is set free by the action of nitrous acid. This urea and hippuric acid together with decayed vegetable and animal matter—that is, dead protein—is then with the aid of bacteria converted into ammonia. Part of this is by means of oxidizing bacteria converted into nitric acid and nitrate in which form it again is partly assimilated by the plants. Part of this nitrate is, however, dinitrified by bacteria, one portion reverting into free nitrogen which goes back to the atmosphere, the other being converted into ammonia which fails to oxidize and is volatilized as a gas, which is absorbed by rain and again returned to the soil. Part of the ammonia is also taken up directly by the plants from the soil.

NEED FOR FERTILIZERS

The fertility of the soil would thus remain practically unchanged if all the ingredients removed in the various farm products were returned to the land where they come from. This is to some extent accomplished by feeding the crops grown on the farm to animals, carefully saving the manure and returning it to the soil. A careful study of the present conditions of farming indicates, however, that as a rule the manure produced on the farm is far from sufficient to maintain its fertility, and artificial fertilizers must be resorted to.

It has been estimated that the yearly loss of nitrogen from soils under cultivation in this country by grain crops alone amounts to over 2,000,000 tons per year. Of this, not over 3 per cent is at present being

supplied from organic fertilizer sources, such as tankage, cottonseed, etc., and this supply is constantly diminishing. The remainder must, therefore, come from inorganic materials. It would, of course, not pay to fertilize to the above extent immediately, but it merely indicates the extent to which nitrogen is needed for fertilizer purposes.

With our constantly increasing population, an increased food supply must be provided, and this can only be assured by increased cultivation and fertilization of the soil. How far behind we lag in this respect as compared with certain European countries, which of necessity have been forced to an intensive use of fertilizer, is shown by the following table:



FIG. 2.—Inorganic nitrogen consumption in United States as given by Nitrate Division of the United States Ordnance Department. Black portions represent inorganic nitrogen used in agriculture. White portions represent nitrogen used in industries and for explosives

Country	Pounds fertilizer used per culti- vated acre	Average yield in bushels per acre, 1905-1913			
		Wheat	Rye	Oats	Potatoes
United States.....	37	14.6	16.0	29.5	95.0
France.....	111	20.2	16.9	30.6	130.7
Germany.....	207	30.9	27.4	53.6	204.8
Great Britain.....	244	33.4	29.1	43.5	211.7
Belgium.....	495	37.0	34.7	71.5	306.0

Prior to the increased use of fertilizer in these countries, the productivity of their soil was similar to our own, and the increase in their food supply, without additional labor and at a cost wholly incommensurate with the gains, has grown in direct proportion to the amount of fertilizer used.

Besides fertilizers, large amounts of nitrogen are also needed for industrial purposes, and the requirements to meet this demand are also steadily increasing.

Nitrate is one of the main ingredients in high explosives and gun powder, and nitration, that is, the treatment of substances with nitric acid, is the fundamental chemical operation in the production of gun cotton for making smokeless powder, celluloid, or other pyroxylin plastics from cotton or paper such as artificial ivory, etc. The dye industry is also to a great extent based on nitration, and numerous drugs, perfumes, and flavoring extracts are also being made in this manner from the coal tar bases, benzol, toluol, and naphthalene.

It is difficult to predict with accuracy to what extent the nitrogen fixation in this country will increase in the future. From statistics presented at a hearing before Congress in 1920, it was estimated that the possible consumption of fixed inorganic nitrogen would be as follows:

	1925	1930
	<i>Tons</i>	<i>Tons</i>
Agriculture.....	190, 000	290, 000
Industries.....	130, 000	150, 000
Total.....	320, 000	440, 000

To supply this need, it is further estimated that the available production from by-product coke ovens will be, in 1925, 130,000 tons; in 1930, 160,000 tons.

The difference would then have to be supplied by importation of Chile saltpeter or by increased products from atmospheric nitrogen fixation plants. For this latter purpose, there are now three plants in this country which with certain modifications would be available and with a combined yearly production capacity equivalent to about 45,000 tons of fixed nitrogen per year. At present only one of these plants is in operation, with a yearly output of only a few thousand tons.

From these figures, it is obvious that we will have to continue to rely to a great extent on the importation of Chile saltpeter, unless steps are taken for providing increased facilities for fixation of atmospheric nitrogen. It is the purpose of this article to describe the different processes which at present are available for this pur-

pose, but, first, a brief reference will be made to the other two sources of inorganic nitrogen, viz, Chile saltpeter and by-product ammonium sulphate.

CHILE SALTPETER

Chile saltpeter is chemically known as sodium nitrate (NaNO_3), the commercial product containing about 95 per cent nitrate, of which $15\frac{1}{2}$ per cent is nitrogen. Like the potash deposits in Germany, there are few natural deposits like the saltpeter deposits in Chile on the west coast of South America. These deposits were discovered by Indians about 1809, who, when lighting a fire, noticed that the ground began to ignite in various directions. They attributed this to evil spirits and consulted a priest, who caused the earth to be examined, thus revealing the presence of nitrate of soda.

The nitrate deposits are located, at altitudes ranging from 2,000 to 6,000 feet, in the desert regions between the 12° and 26° latitudes, a distance of about 500 miles, and perhaps the driest country in the world, with no vegetation whatever.

The nitrate beds generally form horizontal layers covered by three distinct layers or strata of silica, calcium sulphate, and other minerals, the thickness of these layers ranging from 2 to several feet. The nitrate as mined goes under the name "caliche," and the deposits vary in thickness from a few inches to 4 or 5 feet or more. It is like a cemented gravel, the cementing material being the sodium nitrate and sodium chloride and other salts which accompany it. The caliche treated runs from 14 per cent nitrate up to as high as 30 per cent or more, and it does not as yet pay to mine materials with less than 13 to 14 per cent nitrate.

There are many theories advanced regarding the origin of these natural nitrate deposits. Some think that they are original guano deposits; others ascribe their origin to seaweed, because the caliche contains considerable amounts of iodine, and fish skeletons are often found embedded in the strata. Recent theories are that it has its origin in volcanic actions.

PREPARATION OF THE NITRATE

The production of Chile saltpeter comes under two divisions—the mining of the caliche and the refining. The caliche is extracted from the ground by blasting and hand picking, after which it is loaded in carts or light railroad cars and hauled to the refining plants, called "oficinas," by mules or small locomotives. At the plant it is crushed and leached with boiling water, when, due to the different solubility of the nitrate and chloride salts, practically all the

nitrate will be dissolved while the other salts, if already in solution, will be precipitated. The solution is then allowed to cool and, due to the solubility characteristics mentioned above, the nitrate crystallizes out first while the other salts remain in the solution, which is drained off. The nitrate, now in solid form, is placed in drying pans to allow the remaining water to evaporate, and when entirely dry it is packed in bags of about 200 pounds each and shipped by rail down to the different harbors for export.

Most of the Chile saltpeter is used for fertilizer purposes; the nitrogen contained therein being extremely soluble and readily available as food for plants. The nitrogen in this form is thus directly and immediately available and no further changes are necessary.

Considerable amounts of Chile saltpeter are also used for industrial purposes, in which case it must be converted in some other form, the starting point as a rule being nitric acid. This conversion is accomplished by treating the sodium nitrate with sulphuric acid, when a violent reaction takes place, with the result of the formation of nitric acid which is given off as a gas. This passes into condensers where it is condensed to liquid acid. The reaction takes place according to the formula:



STATISTICS

Chile saltpeter was first exported from Chile in 1830, but the amount was small, only a few thousand tons per year. Since then it

Year	Total export in tons	Export to United States	
		Tons nitrate	Tons equivalent nitrogen
1913.....	3,000,000	650,000	100,000
1914.....	2,100,000	620,000	96,000
1915.....	2,200,000	950,000	147,000
1916.....	3,300,000	1,450,000	225,000
1917.....	3,000,000	1,750,000	270,000
1918.....	3,200,000	2,200,000	340,000
1919.....	900,000	330,000	51,000
1920.....	3,000,000	1,350,000	195,000

has, however, constantly increased as seen from the foregoing tabulation, which also gives the export to the United States and its equivalent nitrogen content in net tons.

It is interesting to note how the export dropped in 1915, when the supply of the Central powers in Europe was cut off, and how it since steadily increased until the end of the war, when it again took a big drop.

The proceeds obtained from the export duty imposed by the Chile Government amounts to about 40 per cent of that country's yearly revenue.

The question is often asked: How long will the Chile deposits last? There is quite a difference of opinion in regard to this. It is estimated that the contents of the surveyed areas contained about 300,000,000 tons of nitrate of which about 50,000,000 tons have been mined, leaving about 250,000,000 tons untouched. At the present rate of production this would last about 100 years. It is claimed that the unsurveyed areas are some thirty times larger than the surveyed ones, but undoubtedly of a much lower nitrate content, and it is quite safe to assert that the deposits would last another 250 or 300 years. On the other hand, it is almost certain that long before that time new artificial nitrogen fixation processes will have been developed, by means of which it will be possible to manufacture nitrogen compounds at a much lower cost than the cost of Chile saltpeter, so that the mining of Chile saltpeter will undoubtedly be very materially curtailed long before these deposits are exhausted.

BY-PRODUCT AMMONIA

The by-product coke-oven industry now occupies a vital place for the supply of nitrogen in the form of ammonia. Besides ammonia, the carbonization of the coal in these ovens gives us many other valuable by-products such as benzol, toluol, and naphthalene.

Year	Production in United States			
	By-product coke		Beehive coke	
	Tons	Per cent of total	Tons	Per cent of total
1901.....	1, 180, 000	5	20, 615, 000	95
1907.....	5, 610, 000	14	35, 170, 000	86
1913.....	12, 715, 000	28	33, 585, 000	72
1916.....	19, 070, 000	35	35, 465, 000	65
1918.....	26, 000, 000	46	30, 480, 000	54
1919.....	25, 170, 000	56	19, 650, 000	44
1920.....	30, 835, 000	60	20, 510, 000	40
1921.....	19, 920, 000	78	5, 560, 000	22

It is interesting to watch how these modern by-product coke plants rapidly supersede the old-fashioned beehive ovens, as may be seen from the foregoing tabulation.

A by-product coke oven is a rather complicated structure, but briefly it consists of a large number of parallel chambers or ovens in which the bituminous coal is heated out of contact with the air.

The ovens are separated by flues in which part of the gas generated by the distillation is burned to provide the heat necessary for the coking.

It is from the volatile matter in the coal given off that the by-products are obtained. The ammonia is thus the result of the union of nitrogen and hydrogen, according to some reaction which is not fully known.

The coal contains from 1 to 1½ per cent nitrogen, and of this only about 15 per cent is recovered in the form of ammonia. This means that we only get about 7 pounds of ammonia per ton of coke. The hot gases from the ovens containing the ammonia are cooled and scrubbed with water to remove the tar. They then go to saturators filled with sulphuric acid, and when the gas bubbles through this acid an intimate contact is established between the two and ammonium sulphate is precipitated as a solid salt according to the reaction $2 \text{NH}_3 + \text{H}_2\text{SO}_4 = (\text{NH}_4)_2\text{SO}_4$.

The ammonium sulphate thus formed in the saturators is then drained and dried in centrifugal driers, after which it is ready for sale. It then contains 24 per cent of ammonia equivalent to about 20 per cent of nitrogen.

The remainder of the gas, now freed from ammonia, after leaving the saturators may then be further scrubbed with absorbent oils for recovery of other by-products, and if the gas is to be used for municipal purposes it must be further purified by removing any sulphur that it may contain.

PRODUCTION CAPACITY

The annual productive capacity of the country's existing by-

Year	Coke-oven ammonium sulphate production in United States in tons	Equivalent nitrogen	Year	Coke-oven ammonium sulphate production in United States in tons	Equivalent nitrogen
1910.....	116,000	23,000	1916.....	288,000	59,000
1911.....	127,000	25,000	1917.....	370,000	74,000
1912.....	165,000	33,000	1918.....	388,000	78,000
1913.....	195,000	39,000	1919.....	423,000	85,000
1914.....	183,000	37,000	1920.....	503,000	100,000
1915.....	250,000	50,000	1921.....	346,000	69,000

product coke oven plants is said to be about 35,000,000 tons of coke, which would correspond to a maximum ammonium sulphate output of about 550,000 tons, equivalent to 110,000 tons of combined nitrogen.

The ammonium sulphate production is, however, closely related to the steel-mill business, and the recent slack in this industry was clearly reflected in the coke production, and naturally also the ammonium sulphate output, as shown in the foregoing tabulation.

THE ARC PROCESS

The principle underlying this process is the possibility of chemically uniting part of the free nitrogen and oxygen in the air at such high temperatures as only the electric arc is capable of producing, this being around $5,000^{\circ}$ to $6,000^{\circ}$ F.

Air, which is only a mechanical mixture of nitrogen and oxygen, is thus passed through an electric arc furnace, when a small part (about 2 per cent) of these elements combine chemically and form nitric oxide, NO. This gas, when leaving the furnace, has a temperature of around $1,500^{\circ}$ to $1,800^{\circ}$ F., and in order to prevent the NO from dissociating or breaking up, it must be rapidly cooled to a temperature around 100° F., which is done in two steps. The hot gas is first passed through ordinary steam boilers, which thus serve as coolers, with recovery of heat in the form of steam for use in other parts of the process. The temperature of the gas is lowered to about 300° F. by these boilers, but below this point it becomes necessary to carry out the further cooling in aluminum coolers through which water circulates, without, of course, coming in direct contact with the gas. The reason for this is the fact that nitric oxide at these low temperatures, in the presence of moisture in the gas from water leaking through the tubes, begins to oxidize to nitric acid, which corrodes iron but not aluminum.

From the aluminum coolers the gas mixture is now conveyed to an oxidation chamber, a big sheet-steel tank lined with fire brick. The purpose of this oxidation tank is to give the gas sufficient time to oxidize the nitric oxide NO to nitrogen peroxide, NO_2 or N_2O_4 , this being desirable for the absorption of the gas which is to follow.

From the oxidation tank the gas is carried through an absorption system consisting of several groups of absorption towers, usually five towers in series per group. These towers are of enormous size, the inside being filled with lumps of quartz or other materials which the acid will not attack. Water is admitted to the top of the third tower, and when it trickles down over the quartz filling it meets the ascending gas and is converted into a weak nitric acid. This acid is then pumped to the top of the second tower, where it is used as the absorption liquid, and similarly the acid from the second tower is used for absorption in the first tower, thus gradually increasing in strength. After having thus passed the third tower, about 80 per cent of the NO_2 gas has been absorbed, and this is about all that can

be absorbed by water, the resulting acid from the first tower having a strength of 30 per cent, this being known as weak nitric acid.

The reaction which thus has taken place in the three first towers is as follows: $3 \text{NO}_2 + \text{H}_2\text{O} = 2 \text{HNO}_3 + \text{NO}$.

The liberated nitric oxide, in the presence of oxygen and water, is again converted into nitrogen peroxide and nitric acid.

The remaining 20 per cent of the gas leaving the third tower is now so weak that another solution than water must be provided for its absorption. An alkali solution such as soda ash is used for this purpose in towers 4 and 5, the resulting product being a mixture of sodium nitrate and sodium nitrite, which is evaporated and may be used directly as a fertilizer. If only sodium nitrite is desired the gas is passed into a solution of caustic soda.

The weak acid from the first tower is, however, the main product; but as such a weak acid can not be economically transported, it must be converted into some neutral salt or changed into concentrated acid of 95 per cent strength, which can be shipped in aluminum tank cars. The concentration is accomplished by means of sulphuric acid, which has a greater affinity for the water in the weak nitric acid, thus absorbing it, leaving the nitric acid in concentrated form.

The neutral salt, generally produced from the weak acid, is calcium nitrate, also known as nitrate of lime or Norway saltpeter, because it is the main product of the large nitrate plants in Norway. The calcium nitrate $\text{Ca}(\text{NO}_3)_2$, is thus produced by treating ordinary limestone with the weak acid, the reaction being as follows: $\text{CaCO}_3 + 2 \text{HNO}_3 = \text{Ca}(\text{NO}_3)_2 + \text{H}_2\text{O} + \text{CO}_2$.

The resulting solution is evaporated by the waste heat from the steam boilers before mentioned, and the product is then ready for the market.

This calcium nitrate contains 13 per cent of fixed nitrogen, and is, like Chile saltpeter, an excellent fertilizer, although somewhat hygroscopic. It is, as stated, the main product of the large Rjukan nitrate plants in Norway, which have an annual productive capacity of about 200,000 tons of nitrate, equivalent to about 26,000 tons of fixed nitrogen. Over 300,000 electrical horsepower are used for this, generated in magnificent high-head water-power plants. The power requirements with this process are thus about 12 horsepower years per ton nitrogen fixed, and from this high rate of consumption it follows that the price of the power must be very low in order to make the process an economic success.

The majority of the furnaces used at Rjukan are of the Birke-land-Eyde type, the latest designs having a capacity of 4,000 to 5,000 horsepower each. There are also some Schoenherr furnaces of 1,000 horsepower capacity each. Numerous other types of furnaces

have been proposed and patented, but none except the above-mentioned types have come into any general use. With the exception of the above-mentioned large plants in Norway, the process has had a very limited use. One plant of moderate size has been in operation in France, and the activities in this country have so far been confined to two small installations, one in the West and one in the South

THE CYANAMID PROCESS

The cyanamid process is based on the ability of calcium carbide to absorb free nitrogen, forming a nitrogen compound known as calcium cyanamid, or more generally under its commercial name of simply cyanamid.

The calcium carbide is produced in huge electric electrode furnaces in capacities up to as high as 20,000 electrical horsepower each. The furnaces are kept filled with a mixture of calcined lime and coke, and the electric current passing through the mixture between the electrodes melts the lime to a liquid which then combines with the coke in the interior of the furnace, forming calcium carbide, the reaction being as follows: $\text{CaO} + 3\text{C} = \text{CaC}_2 + \text{CO}$.

The furnace is tapped every 15 to 20 minutes into chill cars, the carbide when leaving the furnace having a temperature of about 4,000° F.

A supply of pure nitrogen free from oxygen is essential with the cyanamid process. It is obtained by liquefying air under intense cooling and high pressure. Such liquid air machines work under pressures of 500 pounds per square inch, and with cooling by expansion the air is reduced to liquid form at 380° F. below zero. By then allowing this liquid air to warm up slightly, pure nitrogen gas boils off first, leaving the oxygen behind in the liquid. The nitrogen is then pumped to the fixation building.

After the carbide has cooled in the cars, it is crushed and powdered. It is then placed in cylindrical perforated paper cylinders in the fixation ovens, and nitrogen from the liquid-air plant is admitted. The ovens are then heated by passing an electric current through a carbon rod which extends through the center of the charge. Due to this heat and the heat from the exothermic reaction, a temperature of about 2,000° F. is reached in the ovens. The carbide absorbs the nitrogen, forming a new chemical compound, calcium cyanamid. The nitrogen fixation is represented by the equation: $\text{CaC}_2 + \text{N}_2 = \text{CaCN}_2 + \text{C}$.

When the absorption is complete, the charge is removed from the oven, allowed to cool, and crushed to a powder. It is then hydrated or treated with a small quantity of water to remove the last traces

of carbide and to slake any free lime present. Sometimes it is also treated with a small amount of oil to prevent dusting. It is then known by the trade name "Cyanamid," and has a nitrogen content of about 19 to 21 per cent.

Cyanamid is extensively used as an ingredient in mixed fertilizers, but during the past few years it has also been used to a great extent as a source of nitrogen for making other products such as ammonia, various ammonium compounds, nitric acid, etc. The next step for either of these is the production of ammonia, which is obtained by heating cyanamid with steam under pressure in so-called autoclaves, when the nitrogen is given off as ammonia gas. This gas may be absorbed in water, producing aqua ammonia, which is used in large quantities for refrigeration and for many general chemical purposes. It may also be used for producing anhydrous ammonia by drying the gas and compressing it. Such ammonia is also used extensively for refrigeration purposes.

By absorbing the ammonia gas in sulphuric acid, sulphate of ammonia is formed, which is separated out by crystallization in the same manner as previously explained under the by-product coke oven process.

Similarly, by absorbing the ammonia gas in nitric acid, ammonium nitrate is formed, which is used to a large extent in high explosives. The nitric acid required for this product may also be obtained from the ammonia gas by oxidation of the ammonia in the presence of a heated catalyst, usually platinum, according to the following reaction: $4\text{NH}_3 + 5\text{O}_2 = 4\text{NO} + 6\text{H}_2\text{O}$.

A mixture of about 10 volumes of ammonia gas and 90 volumes of air is passed over a spongy platinum screen of very fine mesh, heated electrically to a dull red heat, the temperature with the gas passing over it being about 1,000° F. The gas velocity must be very high so as to cut down the time of contact between the gas and the catalyzer to about one one-hundredth of a second. The efficiency of conversion is quite high, about 90 per cent, and the resulting strength of the nitric oxide gas about 8 to 9 per cent, as compared to 2 per cent with the arc process.

The nitric oxide after leaving the catalytic burners is thereafter treated in the same manner as with the arc process; that is, it is passed through oxidation tanks, steam boilers, and aluminum coolers and finally to the absorption towers. The absorption system is, however, much smaller than with the arc process, due to the much higher concentration of the nitric oxide, and for the same reason the weak acid will have a strength of about 45 per cent instead of 30 per cent as with the arc process.

There are a large number of cyanamid plants throughout the world, their total annual productive capacity being possibly in the

neighborhood of 1,250,000 tons of cyanamid, equivalent to a fixed nitrogen content of about 250,000 tons. Based on a power requirement corresponding to $2\frac{1}{2}$ tons of cyanamid per electrical horse-

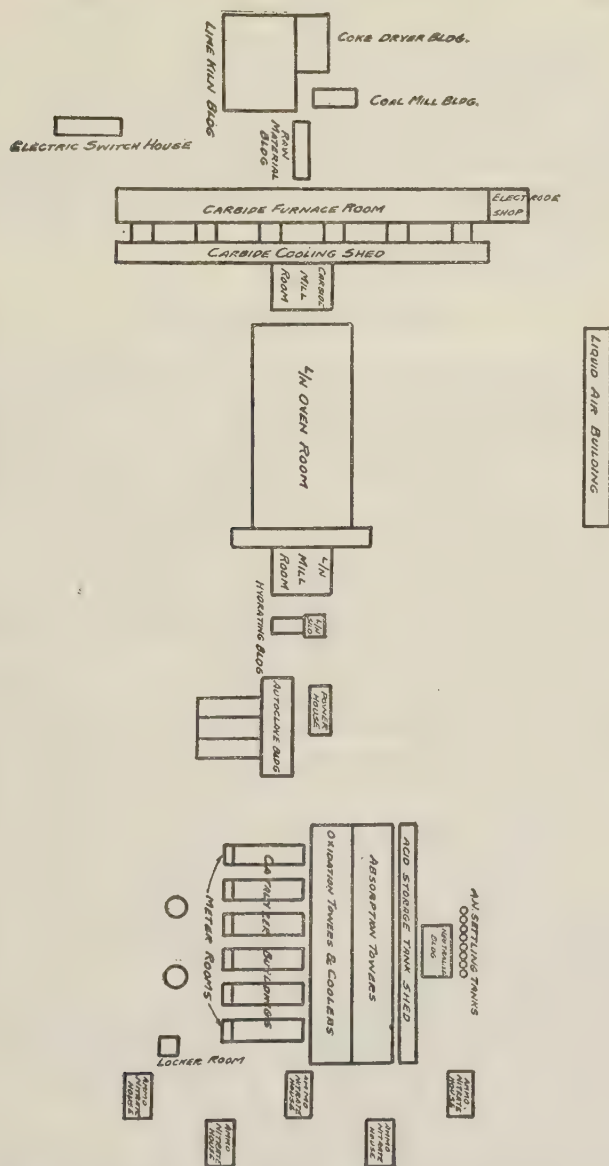


Fig. 3.—General layout of United States Nitrate Plant No. 2

power year, or 2 horsepower years per ton nitrogen fixed as cyanamid, the power for this total output would be no less than one-half million horsepower years. As compared to the arc process, the relative power consumption for the cyanamid process per ton fixed nitrogen is only one-sixth of what it is for the arc process.

The large Government nitrate plant at Muscle Shoals, Ala., built according to the cyanamid process, is generally known under the name of United States Nitrate Plant No. 2, and was built for the Government in 1918 for the production of ammonium nitrate for military explosives, the productive capacity of the plant being 110,000 tons of this product per year. The plant was constructed by the Air Nitrates Corporation, a subsidiary to the American Cyanamid Co., whose process was followed. Incidentally, it might be stated that the plant was completed shortly after the armistice, and one unit (one-fifth the plant capacity) was thereafter put through a two weeks' complete test operation, which thoroughly demonstrated the technical success of the undertaking.

THE CYANIDE PROCESS

The fixation of nitrogen in the form of alkali cyanides has not reached any commercial importance, although considerable research work has been done along these lines and a few small plants actually constructed. One of these plants was built by the Government during the war at Saltville, Va. Its capacity was very small, only 10 tons of sodium cyanide per day, the plans being to convert this cyanide into the highly poisonous gas, hydrocyanic acid, for the war.

The process of fixation on which the Saltville plant was based is known as the Bucher process, the reaction involved therein being as follows: $\text{Na}_2\text{CO}_3 + 4\text{C} + \text{N}_2 = 2\text{NaCN} + 3\text{CO}$.

The raw materials are soda ash and coke in pulverized form to which iron, also in powdered form, is added, its action, however, being purely catalytic. This material is formed into briquettes, thoroughly dried, and then heated in retorts at a temperature around 1,500° F., while nitrogen is passed through the mass. As high as 18 per cent of nitrogen has thus been fixed in the form of cyanide.

When sodium cyanide is once formed it can be converted into ammonia like cyanamid, and the process has the advantage that in this conversion the soda ash can be recovered and used over again. The iron can also be repeatedly used.

A cyanide process has also quite recently been invented in Sweden. A moderate size plant was built and operated for some time, but is now closed down, and the opinions of specialists seem to be divided as to the commercial success of the process.

The process is of the continuously operated type, the materials being kept in continuous circulation in such a manner that the nitrified portions are decomposed into ammonia, leaving a solid residue which is returned to the nitrification building with the addition of some fresh material.

The raw material, consisting of anthracite, sodium carbonate, and iron sponge, is formed into small balls, in which shape they are fed into the furnaces. These are of the shaft type, the material resting on grates which are intermittently turned in order to facilitate discharging and to avoid baking. The furnaces are further of the electrode type, operating on the resistance principle, the balls themselves conducting the electric current from one electrode to the other and becoming in this way heated to the temperature required for the reaction, which is around $1,700^{\circ}$ F. The nitrogen, under pressure, is admitted directly at the bottom of the furnace, and the gases are given off at the top. They contain principally hydrogen and carbon oxide, which are afterwards used as fuel gas for the nitrogen ovens and for drying purposes, etc. The bottom of the furnace is connected to an air-tight conveying system for transporting the cyanide to the ammonium-sulphate building.

A large surplus quantity of nitrogen is needed for the fixation, and a method has been worked out for its production at a very low cost. The process is chemical, the oxygen of the air being bound by an alkali iron to Fe_2O_3 , setting the nitrogen free. This ferric oxide is then reduced by the above-mentioned waste gas from the furnaces and the iron used over again. In practice, air is not used in the manufacture of the nitrogen, but the waste gases from the sulphuric acid factory, as these gases contain only a few per cent of oxygen, thus materially reducing the energy required for binding the oxygen.

The cyanide from the furnaces is, as mentioned, conveyed to the ammonia department where ammonium sulphate is produced in the same manner as for cyanamid, with the exception that the sludge left in the autoclaves after proper treatment is used again as raw material for the furnace charge.

The power consumption with this process is claimed to be about $11\frac{1}{2}$ horsepower years per ton nitrogen fixed as cyanide.

Sodium cyanide is also made by fusing cyanamid with ordinary salt in an electric furnace. This product is extensively used for case-hardening of steel, for the separation of gold from its ore, and for the manufacture of hydrocyanic acid for fumigation of fruit trees. Large quantities of such cyanide is manufactured by the American Cyanamid Co. at their Niagara Falls plant.

THE NITRIDE PROCESS

The fundamental principle underlying this process is the combination of nitrogen with metals, such as aluminum, titanium, lithium, etc., to form nitrides from which ammonia can readily be obtained by decomposition.

The best-developed process of this type is the so-called Serpek process for making aluminum nitride from bauxite (aluminum oxide), coke, and nitrogen according to the reaction: $\text{Al}_2\text{O}_3 + 3\text{C} + \text{N}_2 = 2\text{AlN} + 3\text{CO}$.

Bauxite mixed with carbon is fed into the upper end of an inclined revolving kiln, the necessary heat for heating the mixture to the required reaction temperature of around $3,200^\circ\text{F}$., being supplied by electric current. Producer gas, containing about 30 per cent CO and 70 per cent N_2 , enters the lower end of the kiln and passes through the same in a direction opposite to that of the descending charge, and in the electrically heated zone the nitrogen reacts with the alumina-carbon mixture and forms aluminum nitride, containing about 26 per cent of fixed nitrogen. The carbon monoxide also formed by the reaction is being used for preheating the charge before it enters the kiln.

Ammonia is then formed by treating the aluminum nitride in autoclaves, this reaction being as follows: $\text{AlN} + 3\text{H}_2\text{O} = \text{Al}(\text{OH})_3 + \text{NH}_3$.

In addition to the ammonia, a very pure alumina is obtained, which can be used for metallic aluminum production. The power required is approximately the same as for the cyanamid process; that is, about 2 horsepower years per ton nitrogen fixed as nitride.

Like the cyanide process, the nitride process has not been of any great importance in connection with the nitrogen-fixation problem. A few moderate-size plants have been built in this country and abroad, but it can hardly be said that the process has as yet been fully developed.

THE HABER PROCESS

This process, named after its inventor, Prof. Fritz Haber, of Germany, was introduced there shortly before the war, and was one of the most important factors of insuring Germany of an ample supply of nitrogen during the war, and this with a much lower power requirement than any of the synthetic processes previously described. Germany now possesses two enormous Haber plants at Oppau and at Merseburg. The former, where the terrible explosion occurred in 1921, has a productive capacity equivalent to 100,000 tons of fixed nitrogen per year, and the Merseburg plant twice this; thus a total of 300,000 tons nitrogen per year. Two plants, but of comparatively small capacity, have been built in this country. One of these was built by the Government at Sheffield, Ala., during the war, but has never been in actual operation, except what might be termed experimental operation. The other plant was built in 1921 by the Semet-Solvay Co. at Syracuse, N. Y. The process of these two plants is a modification of the German Haber process developed by the General

Chemical Co., the operating pressure being only about one-half that which is used in Germany.

The Haber process consists, briefly, in passing a mixture of 1 volume of nitrogen and 3 volumes of hydrogen (the constituents of ammonia) at a pressure of from 100 to 200 atmospheres over a suitable catalyzer at a temperature of some 900° to 1,000° F. The nitrogen and hydrogen will then combine and form ammonia according to the reaction: $N_2 + 3H_2 = 2NH_3$.

A single passage of the gas mixture through the catalytic chamber causes a conversion of about 6 to 8 per cent (by volume) of the nitrogen-hydrogen mixture to ammonia, this being recovered either by refrigeration and condensation to anhydrous ammonia or by absorption in water to aqua ammonia, which can again be converted into gaseous form by distillation. The unconverted nitrogen and hydrogen mixture, still under the above pressure, is replenished with a fresh gas mixture corresponding to the separated ammonia, after which it is reheated and returned to the catalytic chamber, thus repeating the cycle.

Besides the mechanical difficulties due to the high pressures at which the process is operated, the solution of the very complicated chemical problems which are involved has required an enormous amount of experimental and research work. It is absolutely essential that the two gases, nitrogen and hydrogen be in a very pure state, as even minute quantities of impurities such as carbon monoxide will be poisonous to the catalytic material and the two gases will refuse to combine, or do so at a very reduced rate. It is this preparation and purification of the nitrogen and hydrogen, and especially the latter, which comprises the chief items of cost in the Haber process.

The problem of providing a durable and suitable catalyst has also been a difficult one. The reaction when the two gases combine to form ammonia can only take place in the presence of what is known as "catalytic" metals. A catalyst, therefore, is simply a substance which promotes the union of two elements with each other, without itself entering into the combination.

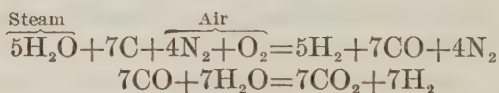
Water is naturally the source from which hydrogen is produced, either chemically or by electrolysis. In the former method, water gas is first generated in a gas producer in the ordinary way by passing steam over incandescent coke. This gas consists of one-half volume of hydrogen, the other one-half being chiefly carbon monoxide, as seen from the following equation: $C + H_2O = CO + H_2$.

In order to remove this carbon monoxide it is found desirable to convert it into carbon dioxide, which can readily be separated by water scrubbing at a pressure of around 25 to 30 atmospheres.

The equation for the reaction is $\text{CO} + \text{H}_2 + \text{H}_2\text{O} = \text{CO}_2 + 2\text{H}_2$, and it is caused by letting an additional quantity of steam react on the gas in a special converter, also with the help of a suitable catalyst. The advantage of this method is obviously that twice*the amount of hydrogen is obtained with the same gas producer. The pressure is obtained with no extra cost because the gas must sooner or later, anyhow, be compressed to a still higher pressure, as previously stated.

Pure hydrogen can be produced by electrolysis of water, but in order that this method shall be commercially feasible cheap power is essential.

The process used at the Government Synthetic Ammonia Plant at Sheffield, Ala., was a modified water-gas process by which the hydrogen and the nitrogen is produced simultaneously. It is thus possible to directly provide a mixture in the right proportions, if instead of steam, a mixture of air and steam is passed over the incandescent coke in the gas producer; or, in other words, if instead of water gas, a semiwater gas is produced consisting of 5 volumes of hydrogen, 7 volumes of carbon monoxide, and 4 volumes of nitrogen. After the 7 volumes of carbon monoxide have been converted into 7 volumes of carbon dioxide and hydrogen, in the manner previously explained, and the gas freed from carbon dioxide, then it contains evidently 12 volumes of hydrogen and 4 volumes of nitrogen or hydrogen and nitrogen in the correct proportions, 3:1, for ammonia. The following equations will possibly make this clearer:



Adding the hydrogen and nitrogen values from the right-hand side of these two equations, we thus get $5\text{H}_2 + 7\text{H}_2 + 4\text{N}_2 = 12\text{H}_2 + 4\text{N}_2 = 8\text{NH}_3$. In the German Haber plants the hydrogen is produced by the water-gas method and the nitrogen by separate lean-gas producers. Some free nitrogen is also required around the plant for various purposes, especially for adjusting the hydrogen-nitrogen mixture before it enters the synthetic reaction chamber. This nitrogen is made by the liquid-air distillation method. This process could, of course, be used for manufacturing all the nitrogen required, but it is a question whether it will be economical unless cheap power can be obtained for driving the refrigerating compressors.

The gases, after leaving the respective producers, are first thoroughly washed by water separately. The main purification, however, is done after the gases have been mixed, and consists in first washing the gas with water under a pressure of around 25 atmospheres for removing the bulk of the carbon dioxide. After this the gas is

brought up to the final process pressure of 100 to 200 atmospheres and washed with chemical solutions for removing the final traces of CO and CO₂, after which it is passed through the catalytic ammonia reaction chamber. In the Sheffield plant the gas mixture is brought up to its final pressure of 100 atmospheres in one step, and the water scrubbing for removing the carbon dioxide is done at this pressure.

The gases which have been converted to ammonia in the catalytic chamber are removed by means of refrigeration or water absorption and the uncombined gases returned to the system to be passed through the catalyzer chamber again until finally combined. The ammonia may be sold as anhydrous or aqua, or absorbed in sulphuric acid or phosphoric acid to produce ammonium sulphate or ammonium phosphate, the same as with the other processes, or a portion may be oxidized and absorbed to form nitric acid, in which the remaining portion of the ammonia may be absorbed to form ammonium nitrate.

In producing hydrogen for synthetic ammonia by the water-gas method, it has been shown how large quantities of carbon dioxide have to be eliminated in the purification. As in the Solvay soda process thousands of tons of carbon dioxide are used each year for which large quantities of limestone are burned, it follows at once that the two processes can advantageously be worked together.

The ammonia gas and the carbon dioxide are passed into a brine solution, and the products obtained are sodium bicarbonate and ammonium chloride, $\text{NaCl} + \text{H}_2\text{O} + \text{CO}_2 + \text{NH}_3 = \text{NaHCO}_3 + \text{NH}_4\text{Cl}$. The sodium bicarbonate, NaHCO_3 , is readily converted into soda ash, Na_2CO_3 , by heating when it loses all its water and part of its carbon dioxide gas, $2\text{NaHCO}_3 = \text{Na}_2\text{CO}_3 + \text{CO}_2 + \text{H}_2\text{O}$. Soda ash or sodium carbonate is extensively used in the glass, soap, paper, textile, and numerous other industries.

The ammonium chloride, NH_4Cl , after proper concentration and drying, is at once ready for the market. It is claimed, but not substantiated, that ammonium chloride, which is a more concentrated nitrogen product than the sulphate and meets the other requirements also, is equal to the sulphate in fertilizer properties, just as potassium chloride is as available for crops as potassium sulphate.

The power requirements for the Haber process are very low unless the hydrogen should be produced by electrolysis and the nitrogen by liquid-air distillation. The reason for this is, of course, the fact that electricity does not enter into any of the reactions but is chiefly used for motive power.

Where the nitrogen and hydrogen are provided by the gas producer method the power requirements will amount to about one-half horse-

power years per ton nitrogen fixed as ammonia, while if electrolytic hydrogen and liquid-air nitrogen is produced the corresponding figure would be around $2\frac{3}{4}$ horsepower years.

THE CLAUDE PROCESS

This process, the invention of M. Claude, of France, is a modification of the Haber process. It is as yet more or less in the experimental stage, but seems to offer great possibilities. Claude thus works with a pressure of 900 atmospheres as compared to 200 with the Haber process. By means of this high pressure about 40 per cent ammonia conversion is obtained per catalyzer unit, and the endothermic reaction will raise the temperature of the catalyst to the required temperature of 900° to $1,000^{\circ}$ F. with only a slight pre-heating, which is readily provided by simply passing the gas through an outer passage in the catalytic chamber. By using three catalyzer units in series, 80 per cent of the gases is converted into ammonia and only 20 per cent needs to be recirculated. The ammonia is readily removed by simply cooling it in a coil submerged in water, when practically all the ammonia will liquefy.

The hydrogen and nitrogen may be obtained in the same manner as with the Haber process previously described. It is claimed, however, that the hydrogen from producer gas can be very efficiently purified at this super pressure. The compressed gas is passed through ether at a low temperature, when all the gases but the hydrogen are dissolved by the ether. The solvent with the gases in solution is drained off, and when expanding to atmospheric pressure the dissolved gases escape, leaving the solvent ready for reuse.

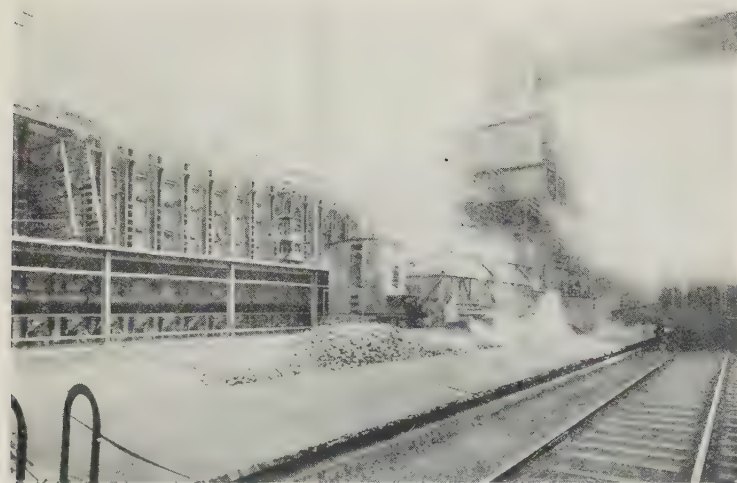
THE CASALE PROCESS²

This is also a synthetic ammonia process which has been developed in Italy, where it is said to be used in one or two plants. It operates at a pressure around 600 atmospheres, or considerably higher than the Haber process, for which reason a higher ammonia conversion should be expected. It is also claimed that a very satisfactory catalyzer has been found which is less affected by impurities in the hydrogen and nitrogen gases.

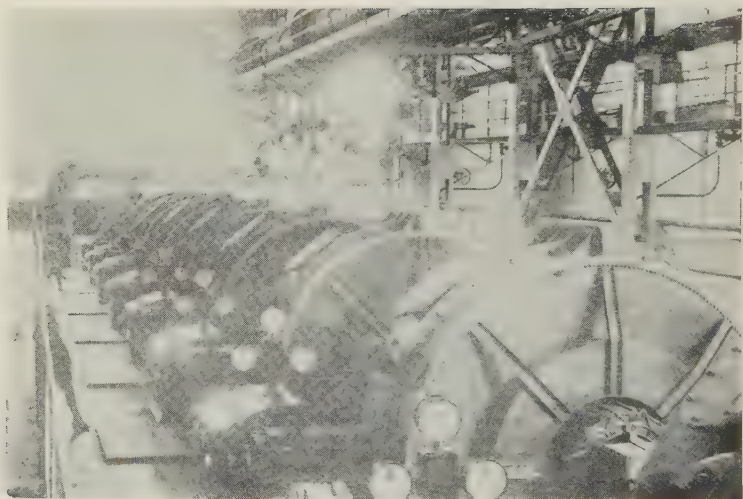
² Since this article was written several Casale plants have been put in operation in Japan, France, and at Niagara Falls.



1. TYPICAL NITRATE BEDS IN CHILE



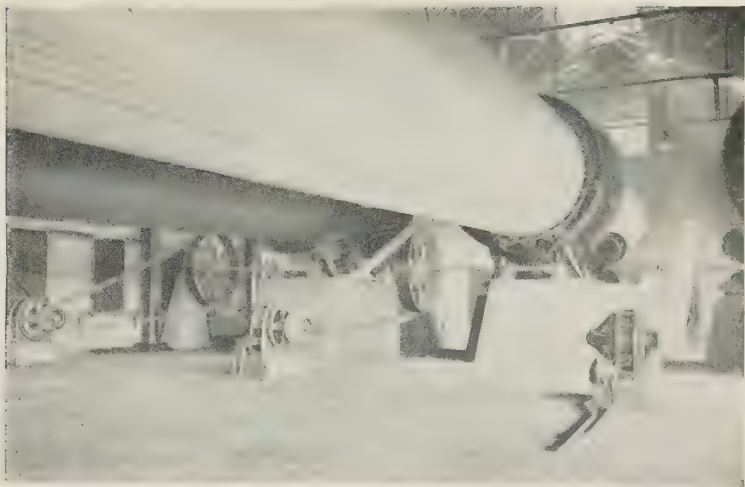
2. BY-PRODUCT COKE OVENS, SHOWING THE COKE BEING REMOVED
FROM AN OVEN TO THE QUENCHING CAR



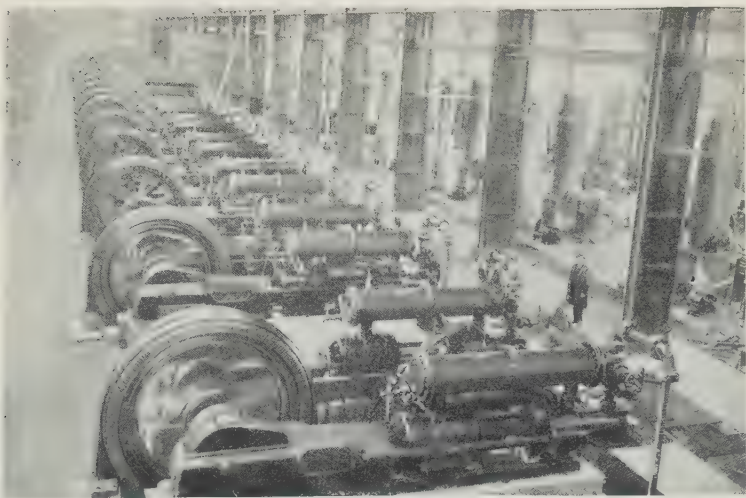
1. GROUP OF 4,000 KW. BIRKELAND-EYDE ARC FURNACES AT THE
RJUKAN NITROGEN WORKS IN NORWAY



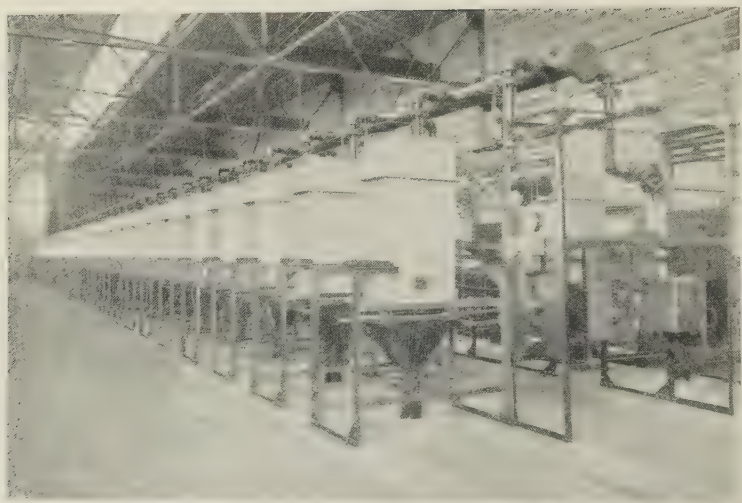
2. GENERAL VIEW OF THE RJUKAN NITROGEN WORKS IN NORWAY



1. MOTOR-DRIVEN ROTARY LIMEKILNS AT THE UNITED STATES
NITRATE PLANT No. 2



2. SYNCHRONOUS MOTOR-DRIVEN AIR COMPRESSORS IN THE LIQUID-
AIR BUILDING AT THE UNITED STATES NITRATE PLANT No. 2



I. CATALYTIC PLATINUM BURNERS IN THE AMMONIA OXIDATION BUILDING AT THE UNITED STATES NITRATE PLANT No. 2



AIRPLANE VIEW OF THE HABER SYNTHETIC AMMONIA PLANT AT OPPAU, GERMANY, AFTER THE EXPLOSION IN 1921

THE PLACE OF PROTEINS IN THE DIET IN THE LIGHT OF THE NEWER KNOWLEDGE OF NUTRITION¹

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The functions of food in the animal body include, first, the furnishing of fuel for conversion into the various forms of energy that characterize living matter, and, second, the furnishing of material for the growth and upkeep of the body itself. From the fact that the solid matter of the active tissues of the body is so largely composed of protein, it is obvious that dietary protein is of the utmost importance in serving this second function of food.

In the utilization of food protein by animals, just as in the utilization of food energy, a certain wastage of material seems to be inevitable. The first wastage is due to incomplete digestibility. There is a marked difference in the digestibility of the proteins of different foods. The animal proteins in particular seem to be completely digested, or very nearly so, when not dried or overcooked, the white of egg constituting an exception to this statement. The proteins of cereals, vegetables, and fruits occupy an intermediate position, being only about 85 per cent digestible. Egg albumin is also of about this digestibility. The proteins of the legumes possess digestion coefficients of 80 or less.

However, these differences in the digestibility of proteins do not in the main depend upon chemical differences existing between them, but rather upon the presence in the food of indigestible carbohydrates, such as celluloses, hemicelluloses, and pentosans. Mendel and Fine have shown² (1) some years ago that these differences largely disappear when the vegetable proteins are fed in a more nearly pure condition. They found that the proteins of wheat were as well utilized as the proteins of meat, and that the proteins of barley and of corn were also probably as well digested. With regard to the proteins of soy beans, navy beans, and peas, they concluded that the presence of indigestible nonnitrogenous materials can not entirely

¹ Read before the Food and Drugs Section of the American Public Health Association at the fifty-first annual meeting, Cleveland, Oct. 17, 1922. Reprinted by permission from the American Journal of Public Health, January, 1923.

² References are to notes at end of paper.

account for their low coefficients of digestion. These proteins appeared to be less readily and completely disintegrated by the digestive processes than the cereal proteins. This resistance to enzyme hydrolysis was even more pronounced with cottonseed proteins.

An interesting light has been thrown upon the digestibility of the proteins of many of the legumes by recent investigations by Jones and his associates in the Bureau of Chemistry (2). In these studies it has been shown that the digestibility of the proteins from certain legumes, including the white bean, the lima bean, and the Chinese and Georgia velvet beans, is much improved by cooking. The value of these proteins in growth experiments on rats in large part depended upon whether or not the proteins were cooked or uncooked. No explanation of this effect of cooking has been given, since it is not predictable from any of the known properties of proteins. About the same time Langworthy (3) and associates reported experiments on men indicating that with most starches cooking is not essential to complete digestibility, though from what is known of the solubility of starch and its physical condition as deposited in plant tissues, it has been widely taught that raw starch is very poorly utilized in digestion. The improvement in the digestibility of raw egg white by cooking is well known, though an unaccountable discrepancy exists among the published reports of experiments concerned with this question.

While the wastage of protein in digestion thus seems to be largely unrelated to its chemical structure and composition, the wastage of protein in metabolism in covering the protein requirements of the body is generally ascribed entirely to the chemical structure of the food protein. From our knowledge of the amino acid make-up of proteins, and of the marked differences in this particular among food proteins, it is readily understandable that the chemical structure of a protein may seriously limit its usefulness to the body. The value of the digestible protein of a food in meeting the protein requirements of the body, allowance being made for this wastage of protein in metabolism, is known as the biological value.

Prominent among investigations of the biological values of proteins, is the work of Thomas (4), reported 13 years ago, and still the most complete study of its kind. Thomas' results are based upon nitrogen balance studies upon himself, and his biological values of the proteins tested express the number of parts of body protein replacable by 100 parts of digestible food protein. This method, therefore, measures the capacity of food proteins in replacing the nitrogenous constituents of the tissues disintegrated and lost in the so-called "wear and tear" processes of the body, or, in the terms of

Folin's theory, the endogenous catabolism. Thomas has given to meat, milk, and fish, values approximating 100, indicating complete utilization of the absorbed nitrogen. On the other hand, to the proteins of corn and wheat have been given values of 30 and 40, respectively, while the proteins of rice, potatoes, and peas are graded 88, 79, and 56, in order. Thus, according to Thomas, animal proteins are two to three times more valuable in adult nutrition than the cereal proteins. Attempts to confirm Thomas' results have not been particularly successful, and several flaws can be found in the planning of his experiments and in his method of selecting some results and discarding others in computing average biological values. The selection of some experimental results in preference to others is always a hazardous undertaking.

More recent determinations of the biological values of proteins have in general indicated* smaller differences between animal and vegetable proteins than those shown by the results of Thomas. Martin and Robison (5) in a recent report have given to wheat proteins a value of 35 and to milk proteins a value of only 51. In analogous experiments on pigs, McCollum (6) has found that at low levels of intake the nitrogen of corn, oats, and wheat seemed to be entirely utilized in the processes of repair. In later experiments (7) on growing pigs at higher levels of intake, results were obtained which, when recalculated according to the method of Thomas, give values of 42 to 48 for the proteins of corn, oats, and wheat, a value of 67 for casein, and a value of 80 for the proteins of milk. Thus, according to these values, the cereal proteins do not seem to be so greatly inferior to milk proteins, even in growing animals, as the values of Thomas would indicate. The evidence obtained by Sherman (8) in his experiments on the efficiency of diets consisting essentially of wheat bread or of corn meal or oatmeal supplemented by only small amounts of milk, also indicate a higher value for these proteins in adult nutrition than have generally been assigned to them.

The work of Osborne and Mendel (9), using an entirely different method, also assigns to the cereal proteins values much nearer those of animal proteins than the work of Thomas. In work on growing rats, using rations complete in every respect except for the protein contained in them, they have expressed the relative values for growth of the proteins tested as the increase in weight (in a four or eight week period) per gram of protein consumed. For the proteins of barley, rye, oats, and wheat, average values of 1.4 to 1.9 grams of gain per gram of protein consumed were obtained. These values may be compared with values of 2.3 and 1.7 obtained for lactalbumin and casein, respectively, in eight-week feeding periods with rats of

comparable weight. Lactalbumin, when fed with certain nonprotein constituents of milk, as in these trials, has been found to be the most efficient protein of all those tested. On the other hand, for the endosperm proteins of wheat contained in patent white flour, the low value of 0.5 gram of gain per gram of protein consumed was obtained. In covering the maintenance requirement of the rat, however, these investigators (10) have shown that the endosperm proteins are just about as efficient as the proteins of the entire grain.

In the last five years, at the Annual Nutrition Laboratory of the University of Illinois, we have conducted a large number of nitrogen balance studies on rats, designed to test the comparative value of the proteins from a number of foods. The results obtained have been used in the calculation of biological values entirely analogous to those of Thomas. We have found that when proteins are fed at a low level, 5 per cent or less of the ration, the utilization of the absorbed nitrogen is in general good regardless of the type of protein fed. The following values represent the average utilization of the absorbed nitrogen of different proteins in covering the nitrogenous requirements of the body when fed at a level permitting little or no growth.

The biological value of proteins fed at a 5 per cent level

Veal -----	97	Coconut -----	77
Milk -----	93	Corn -----	72
Beef -----	92	Soy bean -----	73
Rice -----	86	Casein -----	71
Yeast -----	85	Potato -----	68
Oat -----	79	Navy bean (cooked) -----	29

These figures may be taken as representing the values of the digestible nitrogen from the different foods in repairing the damages that the tissues sustain in the course of their endogenous catabolism, whatever the nature and purpose of that process may be. Too much significance, of course, should not be attached to the small differences between adjacent figures in the table, although differences of 10 or more are probably significant. Each figure is the average of duplicate determinations (seven-day balance periods) on four or more rats. With the exception of the proteins of the white or navy bean, the proteins of the foods examined all seemed to be fairly well utilized. The superiority of the proteins of milk and beef was to be expected, though the high value of the proteins of rice and oats was a matter of surprise. In some individual tests the proteins of rice (brown, unpolished) seemed to be completely utilized. The relative inferiority of casein depends upon its low cystine content, since, by the addition of cystine, its utilization could be raised above 95 per cent.

When fed at a level of 8 to 10 per cent, thus permitting a more or less rapid growth, the proteins of the feeds examined arrange themselves in the following order:

The biological value of proteins fed at a level of 8 to 10 per cent

Veal -----	84	Oat -----	65
Milk -----	85	Soy bean -----	64
Beef: -----		Potato -----	67
8 per cent -----	81	Alfalfa -----	62
10 per cent -----	68	Corn -----	60
Rice bran -----	67	Coconut -----	58
Yeast -----	67	Navy bean (cooked) -----	38
Cottonseed -----	66	Tankage -----	31

Even at this level the differences in nutritive value of proteins do not seem to be extreme, if the proteins of the navy bean and of the packing house by-product known as tankage are disregarded. The differences among the biological values of these 13 protein mixtures are no wider than differences in their digestibility. The rather distinct drop in the value of beef proteins between the 8 and 10 per cent level, we can not explain. Our work with veal seems to indicate a slight superiority of its proteins over those of beef, both for maintenance and growth. We are at present extending this study to the proteins of pork and mutton. Results on two rats with rice proteins at a level of 8 per cent, for two seven-day periods each, consistently indicated a utilization of 85, but until further work has been done on this cereal, we do not feel sufficient confidence in this figure to include it with the others in the table. Unfortunately no tests have been made upon the proteins of wheat as yet, though experiments are now under way to supply this deficiency.

The experimental work just reviewed indicates rather definitely the superiority of meat and milk proteins over vegetable proteins. However, the differences between the two class of proteins are not so great as to constitute a weighty argument favoring animal foods, nor, with few exceptions, are the differences between the vegetable proteins studied of any great moment. The tendency of this investigation, and of others of recent date, is to minimize the differences existing among the protein values of the staple foods of the American diet. However, the biological value of the proteins of the milled flours in promoting growth is undoubtedly distinctly lower than that of the entire grains.

An extensive investigation of the biological values of the proteins of foods has recently been published by McCollum and associates (11), using a method worked out at Johns Hopkins University. In this investigation the food studied was fed in a ration satisfactory in respect to all food factors known, except for a possible deficiency of protein, which was entirely supplied by the food in question.

The protein concentration of the rations was presumably sub-optimal in all cases, so that, except for protein mixtures of good quality, the growth curve of the rats, serving as experimental subjects, was submaximal. Thus, the extent of retardation of growth was taken as an index to the extent to which the quality of any mixture of proteins fell below that of the best combinations previously discovered. This information was supplemented by observations of the animals throughout their reproductive period relative to fertility, infant mortality, and the appearance of senility, as well as observations of successive generations on the same diet. These observations on the maternal functions figured largely in the final judgment of the relative values of the proteins studied.

According to these experiments, the foods studied arrange themselves in decreasing order of the biological value of their proteins according to the following scheme: (1) Beef kidney; (2) wheat; (3) milk, beef liver; (4) beef muscle, barley, rye; (5) corn, oats; (6) soy beans, navy beans, peas.

It will be observed that the proteins of wheat are assigned a higher value than the proteins of milk or of meat, while the proteins of barley and rye are placed on a par with the proteins of meat. These relations are quite contrary to those indicated by other less comprehensive methods of research. One naturally raises the question whether the method used by McCollum is entirely equivalent to the methods previously used. To us there is little doubt but that simple growth experiments and nitrogen balance studies, conducted under proper conditions, can give reliable information of the chemical adequacy of proteins for the purposes of maintenance and of growth. To account for failures in the proper performance of the maternal functions, and for nutritive failures in the second and third generations, by reference solely to the source of protein in the diet, no matter how complete the diet may seem to be in other factors, is, we believe, equivalent to assuming that our present knowledge of nutritive requirements is complete. I doubt whether such an assumption is entirely justified. The more favorable results obtained with the wheat ration than with the milk or meat rations, may be related to the amount of food consumed rather than to its composition.

The measurements of the biological values of proteins may be combined with the measurements of protein digestibility to give what may be called the "net" protein content of a food. For example, if a cut of beef contains 20 per cent of protein of which 95 per cent is digestible, it would contain 19 per cent of digestible protein. Now if only 80 per cent of the digestible protein could be

used to cover the protein requirements of the body, at ordinary levels of protein intake, then the meat could be said to contain $19 \times .80 = 15.2$ per cent of "net protein." Similarly with corn containing 10 per cent of protein, of which 85 per cent is digestible, 58 per cent of the digestible protein being utilizable for structural purposes, the "net protein" content would be $10 \times .85 \times .58 = 4.93$ per cent. Navy beans with 22 per cent of protein, of which 80 per cent is digestible, and of the latter only 38 per cent is available for the repair and growth of the protein tissues, would contain only 6.69 per cent of net protein. Navy beans, therefore, are not as valuable a source of protein as their high content in this nutrient would lead one to expect.

Unfortunately, in the balancing of dietaries, the protein factor can not be so simply assessed, because of the supplementary action of one protein upon another. The value of a protein in the diet depends not only upon its own inherent value, but upon its ability to enhance the value of other proteins. Several proteins have been shown to possess the property of correcting the chemical deficiencies of other proteins, so that a mixture of two proteins may have a greater biological value than the mean value of the proteins themselves. As an illustration of this supplementing effect of proteins, we may cite an experiment on corn proteins, skim milk proteins, and a mixture of the two in the proportion of 3 of corn protein to 1 of milk protein. The average biological value of the corn protein was 61, of the milk proteins 84, and of the mixture, 75, all rations containing 10 per cent of protein. Now the weighted mean of the values for corn and milk in the ratio of 3 to 1 is 67. The difference between the mean value, 67, and the value actually obtained, 75, represents the supplementing action of the milk proteins. A more striking instance yet is afforded by a mixture of corn proteins and tankage proteins. Alone, these proteins were found to have values of 61 and 33, respectively. Fed in the proportion of 3 to 1, the mixture was found to have a value of 65, higher than that for corn proteins alone.

Recent work indicates that while vegetable proteins do not in general supplement each other effectively, the proteins of milk, meat, and eggs do exhibit marked supplementary properties, thus giving to animal foods a twofold importance in dietetics. When it is considered in this connection that on the average some 43 per cent of the protein of the American diet is derived from milled cereals, and almost 9 per cent from legumes, making 52 per cent of proteins of exceptionally low biological value for growth, the importance of animal proteins in the diet is obvious, particularly

for children and convalescents. It is perhaps no exaggeration to say that the importance of animal proteins in the diet resides as much in their capacity of supplementing cereal and legume proteins as in their own excellence.

As mentioned above, our nitrogen balance data indicate a better utilization of protein the lower the level at which it is fed, until at the maintenance level proteins, with few exceptions, are all well utilized. Confirmation of this view may be found in the work of Osborne and Mendel. A practical corollary following from this statement is that with adult animals, to which high protein diets are not essential, the kind of protein consumed would seem to be largely a matter of indifference. For men, the protein minimum is something like 30 grams per day for a man of average weight. Such a man consumes, however, close to 100 grams of protein per day, so that even though the digestibility and the quality of the dietary protein were relatively poor, there would be little danger of a protein deficiency if the values given above are correct. If the man were consuming even much less protein than 100 grams, there would be a tendency for the smaller amounts to be digested more completely and subsequently utilized more completely in metabolism, so that here also the danger of a protein deficiency would seem to be remote. The theory that pellagra is a disease involving primarily a deficiency of protein, therefore, finds no support from such considerations. These statements assume, of course, that the satisfaction of protein requirements is simply a matter involving the chemical adequacy of the dietary proteins and the amount consumed.

Obviously, with growing children and nursing mothers, the quality and quantity of protein consumed is a matter of far greater moment, and until reliable information as to protein requirements in such cases is at hand, the safe procedure would be to provide liberally with proteins of good quality and of good supplementing capacities. Such proteins are contained in milk, meat, fish, and eggs. The presence of these foods in the diet will permit the use of considerable amounts of other foods whose proteins are poor in quality and low in concentration, without reducing the net value of the mixed proteins of the diet to the danger point. The legumes, with the exception of soy beans, while high in protein, are not suitable foods for this purpose, on account of the relatively low value of their proteins, both as regards digestibility and subsequent utilization. With beans, again excepting the soy bean, the amino acid cystine seems to be the factor limiting the biological value. One would expect, therefore, that meat proteins or egg proteins, com-

paratively rich in sulphur, would supplement the proteins of beans better than milk proteins, since casein, the main protein of milk, is known to be very poor in respect to its content of cystine. Recently the value of the proteins of nuts has been demonstrated (12). Their high content of protein, of fairly high digestibility and apparently of good biological value, should commend them as a good source of dietary protein.

Any complete survey of the place of proteins in the diet must include some consideration of the conclusion so frequently expressed, that protein consumed in amounts much above the actual requirements of the body may exert harmful physiological effects. In support of this conclusion, reference is often made to the well-known work of Chittenden on the low protein dietary. However, in these classical experiments, the absence of control groups maintained upon the usual level of protein renders questionable the deduction that the observed benefits of the low protein dietaries adopted were due solely, if at all, to the reduction in protein intake. In fact, the recent success of McCollum in raising rats on diets containing as high as 70 per cent of protein certainly is a strong argument against ascribing to protein deleterious physiological effects when fed even in great excess. Several instances in recorded human experience may be cited to the same purpose. However, while it is probably true that protein may be indulged in to great excess without any immediate ill effects, or even with no pronounced ill effects at all, the wisdom of so doing may be questioned. The comfort of an individual, as well as his mental and physical efficiency, are undoubtedly adversely affected under certain conditions by a high-protein dietary. The degree and type of activity of the individual should be considered, and the protein intake graded in direct proportion to the muscular activity. The well-known stimulating action of protein foods on metabolism probably is related to vitality and stamina, and should be numbered among the favorable effects of protein as a nutrient. At the same time the pronounced heating effect of protein, associated with its stimulating action on metabolism, will naturally and rightly lead to a seasonal variation in the popularity of protein-rich foods.

This abbreviated consideration of the importance of protein in the dietary, involving a study of the waste incidental to its utilization by the body, its proper function in the body, and its physiological effects, illustrates how complicated the problem of protein requirements has become and how difficult it is to make hard and fast recommendations. In pedagogy the subject of protein requirements is still the despair of the teacher of the physiology of nutrition.

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THE STORY OF THE PRODUCTION AND USES OF DUCTILE TANTALUM¹

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In the year 1801, Hatchett discovered the oxide of a new metal in a black mineral which he obtained from the British Museum. He named the metal columbium and the mineral columbite, because the mineral originally came from Massachusetts. A year later Eckeberg made a similar discovery while working with some new minerals from Sweden, and he named the new metal which he discovered tantalum. Subsequently, a number of other investigators announced the discovery of new metals in tantalum- and columbium-bearing ores which were all shown to be mixtures of these two, and in 1866 Marignac developed his classical method for their separation, which depends upon the difference in solubility of their double fluorides with potassium.

The first mention of tantalum in the metallic form is that obtained by Berzelius. In 1824 he obtained a very impure product, containing not over 60 per cent of metal and having a specific gravity of 10, by reducing potassium tantalum fluoride with potassium. In 1902, Moissan produced a very hard and brittle form of tantalum high in carbon and having a specific gravity of about 12.8. In 1903, Dr. W. von Bolton, working in Germany, developed a process for the production of tantalum of sufficient purity to make it possible to produce drawn filament wire for incandescent lamps, and during the years 1905 to 1911 probably over 100,000,000 of these lamps were produced. This material as a filament wire was then replaced by tungsten.

About 20 years ago the writer became interested in these elements and devoted a number of years to the study of their various compounds and to the determination of their atomic weights. More recently, believing in the commercial value of this metal, an investigation was begun with the idea of producing the metal in commercial quantities. During the present year this investigation was brought to a successful conclusion, and it is now possible to produce tantalum characterized by high purity and capable of being worked into sheet, rod, or wire.

OCURRENCE OF TANTALUM

The elements tantalum and columbium are usually found associated with each other in their ores. The most important minerals containing these elements are columbite and tantalite, which are really

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iron salts of columbic and tantallic acids. Usually a part of the iron is replaced by manganese, and small amounts of titanium, tin, and tungsten are almost always present. To lesser extent it occurs with rare earths in samarskite and other minerals.

For the production of metallic tantalum, tantalite is the most desirable ore and should contain at least 60 per cent of the oxide and only a few per cent of columbium oxide.

The first step involved in the production of metallic tantalum is the extraction of pure compounds of tantalum from the mineral tantalite. This involves the separation of the columbium which may be present.

There are a number of methods available with which to attack this ore. As the most suitable method for the separation of tantalum from columbium is through the difference in solubility of the potassium double fluorides, the method employed should be directed toward the easiest method of production of these compounds. The pulverized ore may be fused with potassium bisulphate. On leaching this fusion, the acids of tantalum and columbium remain insoluble and can be dissolved in hydrofluoric acid and treated with potassium fluoride, or the mineral may be fused with acid ammonium fluoride and the tantalum precipitated from the solution of the melt by means of potassium fluoride.

A method which is more easily carried out on a large scale is the fusion of the finely pulverized ore with potassium hydroxide, which converts the tantalum and columbium into soluble columbates and tantalates. The filtered solution containing these salts may be treated with a mineral acid, preferably nitric or sulphuric acid, which precipitates the insoluble acids of tantalum and columbium. After washing, these are dissolved in hydrofluoric acid and the solution is treated with sufficient potassium fluoride to produce the double fluorides K_2TaF_7 and $K_2CbOF_5H_2O$. These two salts are readily separated by crystallization, inasmuch as the columbium salt is about 12 times as soluble as the tantalum double fluoride.

The oxide of tantalum can be produced from this double fluoride by treating the solution of the salt with ammonia, and precipitating the acid, which can be washed and then ignited to oxide.

PRODUCTION OF METALLIC TANTALUM

It is perfectly evident at the present time that the early attempts to produce metallic tantalum, involving such methods as the reduction of the oxide with carbon in an electric furnace, the reduction of tantalum oxide with aluminum by the Thermit process, or the reduction of the oxide by means of misch metal (mixed cerium earth metal), could not have given a product characterized by any degree of purity, and most certainly a metal which could not be subjected to any mechanical working.

Metallic tantalum powder can be produced by the reduction of the double fluoride with metallic sodium or potassium. It is impossible by this process to produce a powder characterized by high purity. For best results by this method the reaction should be carried out in a vacuum, the boats or crucibles containing the mixture of double fluoride and metallic sodium or potassium being placed in a tube or furnace which can be evacuated before the mixture is raised to the reaction temperature.

The product from this reaction can be treated with water and mineral acids in order to free the metal powder as completely as possible from adhering salt and other impurities. This powder is then compressed into bars and subjected to heat treatment and finally fusion in a vacuum furnace, the high temperature of fusion eliminating the impurities which may be present. If this process has been completely successful, the fused metal will be found to be ductile and susceptible to mechanical working.

The most characteristic chemical property of tantalum is its unusual resistance to chemical corrosion. It is not attacked by hydrochloric or nitric acids or by aqua regia, either hot or cold. It is not attacked by dilute sulphuric acid at ordinary or more elevated temperatures, but appears to be slowly attacked by boiling concentrated sulphuric acid. Solutions of caustic alkalis do not attack the metal. Hydrofluoric acid seems to be the only chemical agent which will attack it, and in the case of very pure metal and very pure hydrofluoric acid the action is very slow. A mixture of hydrofluoric and nitric acids will attack the metal with avidity, causing it to go into solution as tantalum fluoride.

If tantalum is heated in the air, the surface becomes blue at a temperature of about 400°C. , and at a somewhat higher temperature nearly black. Above a dull red heat the white oxide is produced and the metal gradually burns. This metal combines with avidity with hydrogen, oxygen, or nitrogen. It will take up seven hundred and forty times its own volume of hydrogen, producing a very coarse-grained brittle product.

Tantalum containing dissolved gases will be harder than the pure metal, and if their quantity is appreciable the metal may even be brittle, so that all annealing or heating operations with tantalum must be carried out in a vacuum. Tantalum burns readily when heated in chlorine gas, producing the volatile pentachloride. Solutions of chlorine, however, are without any action on the metal. Tantalum is not affected by any of the chemicals or antiseptics used in dentistry or surgery, probably without exception.

PHYSICAL PROPERTIES OF TANTALUM

It has been possible to produce metallic tantalum of an exceedingly high degree of purity, and to produce it in commercial quantities,

having a purity of at least 99.5. The pure worked material resembles platinum very much in color and appearance. Its melting point may at present be taken as 2,850° C. The specific gravity of the worked metal is 16.6.* The pure metal is characterized by toughness and by its great ductility and malleability.

It has been found possible to reduce a bar of tantalum about three-eighths inch in diameter to wire of only a few mils in diameter without any intermediate heating to the annealing or equiaxing temperature, although the material is subject to strain hardening, resembling the more common metals such as silver or copper in this respect. Tantalum, however, resembles tungsten and molybdenum in that they may all be worked severely at temperatures below their equiaxing temperatures. Copper and silver may be worked at room temperature, but these metals become quite rapidly strain-hardened so that a further reduction makes it necessary to anneal the metal. Tungsten and molybdenum must be worked at elevated temperatures in the early stages, and if they are to be worked at room temperature in the finer sizes any operation corresponding to ordinary annealing must be avoided. Tantalum may be worked at room temperature to a remarkable extent without annealing.

The tensile strength of drawn tantalum wire may reach 130,000 pounds, which is considerably more than that of hard drawn copper, nickel, or platinum, but less than that of molybdenum or tungsten.

The linear coefficient of expansion is more than that of molybdenum or tungsten and only slightly less than platinum.* For this reason it is possible to seal tantalum into glass.

	Tungsten	Tantalum	Molybdenum	Platinum	Copper	Nickel
Density.....	19.6	16.6	10.2	21.4	8.80	8.84
Atomic value.....	9.4	10.9	8.8			
Tensile strength, lb. per sq. in.	490,000	130,000	260,000	¹ 54,000 ² 42,000	¹ 62,000 ² 35,000	¹ 120,000 ² 70,000
Compressibility, kg. per sq. cm.	0.28×10^{-6}	0.50×10^{-6}	0.47×10^{-6}		0.76×10^{-6}	
Young's modulus of elasticity, kg. per sq. mm.	42,000	19,000				22,000
Melting point, deg. C.....	3,350	2,770	2,550	1,755	1,083	1,452
Boiling point, deg. C.....			3,617	3,907	2,310	
Specific heat, cal. per gram per deg.	0.034	0.0365	0.072	0.0323	0.0936	0.1084
Linear coefficient of expansion per deg. C.....	4.3×10^{-6}	7.9×10^{-6}	5.15×10^{-6}	8.84×10^{-6}		13×10^{-6}
Thermal cond. in cal. per cc.	0.35	0.130	0.346	0.1664	0.7198	0.140
Temp. coefficient of expansion.	0.0051	0.00335	0.005	0.0039	0.00393	0.0066
Electric resistance, microhm per cc. at 25 deg. annealed...	5.2	14.6	4.8	9.97	1.87	6.4

¹ Hard.

² Annealed.

The electrical resistance is quite high, about eight times that of copper and about three times that of tungsten. The accompanying table gives the physical properties of tantalum as far as they are at present known, and also those of a number of other metals in comparison.

HIGH CHEMICAL RESISTIVITY GIVES IT MANY USES

In considering the possible uses for this metal we must take into account its high melting point, its resistance to chemical corrosion, and its tendency to absorb all of the common gases. We must also remember that we are limited by its relatively low temperature of oxidation. Tantalum seems to be a very desirable metal for the manufacture of certain dental instruments and dental spatulas, and undoubtedly for other dental and surgical tools or instruments. The metal is not attacked by any of the antiseptics or chemicals used and can be readily sterilized by heat. A surface film of hard material about as hard as agate can be produced on the metal by proper heat treatment. It will probably be found possible to harden the material throughout, thus combining all the advantages of tempered steel with absolute chemical inertness.

It has been suggested for use in the manufacture of pens and analytical weights. Its use in chemical laboratories and in the chemical industries as containers, parts of pumps, and other equipment will undoubtedly depend upon the cost at which the metal can ultimately be produced.

Tantalum is suitable for cathodes in electrochemical analysis. In some respects it is more suitable than platinum. For instance, zinc may be plated directly upon the tantalum, as it does not alloy with the metal. Gold or platinum can be deposited upon the metal, as they can be removed by aqua regia without attacking the electrode.

Undoubtedly tantalum in the form of sheet, wire, or ribbon will find application in the manufacture of radio sending and receiving tubes. The property of tantalum of absorbing gases would seem to make the metal its own "getter" in vacuum tubes, and would tend to maintain the high vacuum required, particularly in the sending tubes. It would seem that some part of the lamp made of tantalum could be so constructed that at all times a portion of the metal would be at the proper temperature to absorb gas and would, therefore, tend to maintain a vacuum equilibrium within the bulb.

USE OF TANTALUM AS AN ELECTROLYTIC VALVE

Tantalum has interesting possibilities on account of its property of acting as an electrolytic valve.

If two plates of bright tantalum metal are placed in an electrolyte and the two plates connected to an electric battery, there is an

instantaneous flow of current similar to that between plates of the better known metals. Within a few seconds the current flow will drop to a very small comparative value, providing the battery voltage is not too high. The order of the current flow will become that of 1 milliamperes and less with impressed direct current voltage up to 75 volts, when sulphuric acid of the strength ordinarily used for storage batteries is the electrolyte. This drop in current flow will be accompanied by the formation of a film on the tantalum anode, presumably of tantalum oxide. This film often shows beautiful iridescent colors.

If a tantalum plate and a lead plate are placed in an electrolyte and a source of alternating current of the usual commercial frequency is connected to the tantalum and lead plates, the current flow in one direction will be almost entirely shut off and a pulsating direct current will be obtained. In such a set-up this flow of current is accompanied by electrolytic action with evolution of hydrogen gas at the tantalum and oxygen at the lead. The action of the tantalum is, therefore, such that electrons are permitted to flow from the tantalum to release hydrogen ions but are prevented from passing from oxygen ions into the tantalum.

The current derived from this apparatus may be utilized for charging storage batteries, for the electro-deposition of metals, and various other electrochemical actions requiring a direct current.

It is possible, by using two tantalum electrodes in a single cell, so to rectify the current that both half waves of alternating current pass in the same direction. This current may be smoothed out by a suitable series of inductances and capacities to give what is practically a constant direct current.

The efficiency of tantalum as a valve with respect to leakage of the current varies with the impressed voltage, with the electrolyte, current density, etc. Due to the fact that tantalum is very inert toward the chemical action of solutions, there is a wide choice of electrolytes and the life of the tantalum appears practically unlimited.

For a charging set-up with a 6 to 8 volt battery the energy efficiency is approximately $33\frac{1}{3}$ per cent, which compares favorably with rectifiers of the hot and cold electrode type and the mechanically vibrating rectifiers.

The tantalum battery charging rectifier is noiseless in operation, has no moving parts, and requires attention in only one matter, which it has in common with the storage battery itself—that of distilled water being added to replace evaporated and decomposed water of the electrolyte.

In addition to functioning directly as a rectifier for obtaining continuous current, apparatus built along similar principles may be

used for electrolytic condensers and electrolytic detectors and possibly lightning arresters.

Among other metals which have this property of valve action more or less in common with tantalum are magnesium and aluminum. However, owing to the ready susceptibility of both these metals to chemical corrosion, they have not proved very suitable as sources of direct current. Condensers and lightning arresters for high potential transmission lines are commercially used with aluminum plates.

THE COMPOSITION OF THE EARTH'S INTERIOR¹

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Curiosity is one of the dominant characteristics of man. From early childhood he seems impelled to examine every object within his reach and when possible to open it up to see what makes the wheels go 'round. But the urge which led Pandora so deeply into trouble is, in another aspect, called science, and provides the mainspring for the procurement and classification of facts. Scientific investigation is merely a manifestation of curiosity concerning those things which we see or know about but do not understand.

It is only natural that the internal constitution of the globe upon which we live should excite our curiosity. Although the diameter of the earth is 8,000 miles, the deepest borings have penetrated down to a depth of little more than 1 mile; it is as if a sphere the size of an orange were inhabited by diminutive beings who had explored their globe only at the surface and to a depth of one-fourth the thickness of the paper on which these words are written. The inaccessibility of the earth's interior, and the apparently insuperable difficulties which are presented, only serve to sharpen our zeal for finding out something about it. Nowadays we are becoming more accustomed to investigate things which can not be seen, and in this paper it is hoped to show what can be learned of the earth's interior, even though it be beyond the reach of direct observation.

The principal sources of information concerning the interior of the earth are as follows: (1) The constant of gravitation, from which the total mass and average density of the earth are determined; (2) the constant of precession and other astronomic and geodetic data from which the moments of inertia of the earth may be calculated, the moment of inertia allowing important inferences to be drawn concerning the density distribution within the earth; (3) the known flattening of the earth, as determined from the data of geodesy, with which any assumed distribution of mate-

¹ The substance of this paper appeared, under the title "Density distribution in the earth," in the *Journal of the Washington Academy of Sciences* (vol. 13, 413-428, 1923) just before Mr. Williamson's death. The paper is now being republished, with slight rearrangement and with minor additions.

rials must harmonize; and (4) seismologic data from which the elastic constants of the materials in the interior may be computed. These facts, together with the elastic constants of various rocks as measured by the authors,² provide the basis for the present estimate of the density and composition of the earth at various depths.

The bearing of the above classes of data on the constitution of the earth's interior will first be discussed briefly.

MEAN DENSITY OF THE EARTH

The constant of gravitation from direct experimental observation is known to be $6.66 \times 10^{-8} \text{ cm}^3/\text{g.-sec.}^2$. This fixes the average density of the earth at 5.52; that is, the earth is five and one-half times as heavy as an equal bulk of water. This fact alone allows certain qualitative inferences to be drawn concerning the interior. The average density of the surface rocks is about 2.7 and no ordinary rock has a density much above 3; therefore in all probability the density near the center must be considerably higher than 5.5 in order that the average density of the whole earth may have the correct value. The precise manner in which the density varies with depth and the magnitude of the central density are questions which long ago attracted the attention of geophysicists. Several empirical laws have been proposed for representing the density at a given distance from the center of the Earth. Among the best known are those of Laplace³ and of Roche,⁴ either of which, with an assumed surface density 2.7, indicates that the central density is somewhat above 10. These empirical "laws," of course, can not be expected to give a true representation of density in the interior; the supposed continuity of density change from the surface to the center, and the magnitudes of the densities at various depths, rest upon insecure hypotheses. Yet it is an interesting circumstance that either law, as will be shown later, affords a rough qualitative indication of the earth's density at various depths.

The high density at the center obviously may be due either to the presence of heavier material, presumably iron or nickel-iron, or to a diminution of volume by the tremendous pressure existing at great depths—or both factors may enter. It has often been assumed that the increase of density with depth is merely the result of the compressibility of the homogenous material. If this were true, Laplace's law, for example, could be used to calculate the compressi-

² Journ. Franklin Inst. 195, 475-529. 1923.

³ Laplace's equation, also derived independently by Legendre, is $\rho = \rho_0 \frac{\sin qr}{qr}$ in which ρ is the density at any distance r from the center, ρ_0 is the central density, and q is a constant determined by the known total mass of the earth.

⁴ The law of Roche is $\rho = \rho_0 (1 - kr^2)$, in which k is a constant which also can be determined from the earth's total mass or mean density.

bility of the earth at the surface and in the interior, and there would be no need to postulate a heavy material at the center, the earth, on this basis, consisting throughout of silicate rock like that found at the surface. There is no a priori reason why this could not be so, but clearly other lines of evidence must be examined before an answer to this question can be secured.

MOMENT OF INERTIA OF THE EARTH

It is obvious that for a given mass (or for a given mean density) the moment of inertia depends on the distribution of density^{*}; e. g., if there is heavy material at the center and light material at the surface the moment of inertia would be considerably less than if the central density were smaller than that of the surface.

It is interesting in this connection to recall the old puzzle "How to distinguish between two hollow shells, one of gold, the other of silver, if their diameters and masses be alike, and both painted."⁶ Since gold is denser than silver, the volume of the gold shell is less than that of the silver shell, and therefore, on the whole, its mass is farther from the center and its moment of inertia greater. Hence to decide which is the gold and which the silver sphere, it suffices to compare their moments of inertia. This may be done by allowing them to roll down a rough plane, whereupon the gold sphere will move at the slower speed. In an analogous manner, the moment of inertia of the earth may be used to decide which of two proposed distributions of matter within the earth is the more plausible. The moment of inertia itself is not sufficient to fix the density distribution; it can be used, however, as an important check on a density curve deduced from other considerations. The moment of inertia of the earth about the polar axis is known to be close to 8.06×10^{44} g.-cm². Since the moment about the equatorial axis differs from that about the polar axis by only one-third of 1 per cent. very little error is introduced by dealing with a *sphere* of radius equal to the mean radius of the earth and having a moment of inertia equal to the value just mentioned.

The moment of inertia of the earth if of uniform density from surface to center would be 9.7×10^{44} , significantly higher than the true value. In other terms, the moment of inertia of the earth is that of a homogeneous sphere of density 4.6. From this fact, also, follows the qualitative conclusion that in general the density must in-

* The moment of inertia of a sphere with its mass symmetrically distributed about the center is

$$C = \frac{8\pi}{15} \int \rho d(r)^4 \quad *$$

In which ρ is the density at distance r from the center. For a homogeneous sphere this becomes

$$C = \frac{8\pi}{15} \rho r^4 = 0.4 Mr^2$$

M being the total mass.

⁶ See P. G. Tait, *Dynamics*, London, 1895.

crease toward the center, in harmony with the inference already drawn from the high density of the earth as a whole.

THE ELLIPTICITY OF THE EARTH

The earth, as is well known, is not a true sphere, but is flattened at the poles, approximating very closely to an ellipsoid of revolution. The ellipticity, or flattening, is about $1/297$; that is, the polar diameter is $1/297$ less than the equatorial diameter. Now the amount of of this flattening depends upon the way in which the density varies within the earth. Thus, if the earth were of uniform density the flattening would be $1/232$. But although it might seem that the flattening would provide an independent means for determining the density distribution within the earth, it so happens that a distribution which will satisfy the moments of inertia about the two axes will yield almost exactly the right value for the ellipticity.⁷

TRANSMISSION OF EARTHQUAKE WAVES

Perhaps the most useful source of information concerning the earth's interior is furnished by the velocities with which earthquake shocks are transmitted through the earth. It has been shown from the theory of elasticity that any disturbance in a sphere of elastic isotropic material should give rise to various kinds of waves traveling with velocities depending only on the density and elastic constants of the material at each point. Waves of two of these kinds would pass through the sphere, while the others, which are less simple to analyze, would travel over the surface. A seismograph recording the time of arrival of the various waves at some other point would show the arrival first of the two waves passing *through* the earth and later that of the various surface ones. One of the "through waves" consists of transverse vibrations, while the other consists of longitudinal vibrations and travels with a higher velocity.⁸ These through waves should theoretically be easily distinguished from the surface waves by the circumstance that their apparent velocity (i. e., the velocity obtained by comparing their times of arrival at various points on the surface with the corresponding distances from the origin) should vary with the distance, whereas the velocity of the surface waves should be constant. The records of earthquakes as obtained by sensitive seismographs reveal these expected features, and we may with considerable confidence use the theoretical relations between velocities and elastic constants to calculate the rigidity and the compressibility of the material

⁷ Cf. W. D. Lambert, The internal constitution of the earth. Journ. Wash. Acad. Sci., 10, 127. 1920.

⁸ The velocities of the transverse and longitudinal waves are respectively: $V_s = \sqrt{R/\rho}$ and $V_p = \sqrt{(K+4R/3)/\rho}$, ρ being the density, R the rigidity, and K the bulk modulus.

far within the earth. The data obtained from seismograms, moreover, indicate that the material of the earth, except at the surface, may be treated as (megascopically) isotropic. It is fortunate that this is the case, since otherwise the mathematical treatment of seismologic data would be extremely difficult.

Starting from the time-distance curve—that is, the times of arrival of a disturbance at given distances along the surface—by a comparatively simple process one can calculate the elastic constants of the material of the earth at various depths. The steps in the process are as follows: (a) From the slopes of the time-distance curves the

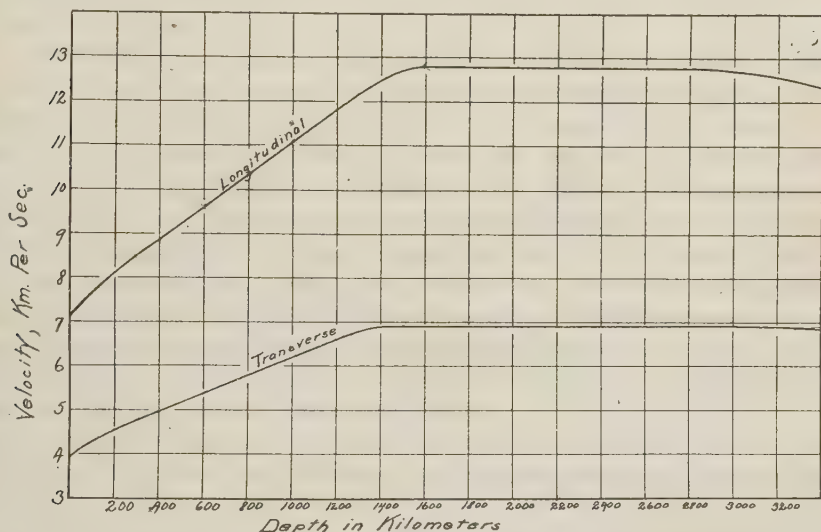


FIG. 1.—The velocities of longitudinal and transverse earthquake waves at various depths below the surface of the earth as calculated from seismologic data

apparent surface velocities of each of the varieties of through waves is obtained; (b) by graphical integration of a certain function of the surface velocity there is obtained the maximum depth for a wave traveling between two points separated by a specified distance; (c) from a very simple relation the true velocity at this depth is determined; (d) and finally, the bulk modulus K and the rigidity R are calculated from the equations connecting these quantities with the velocities.⁹

With the time-distance curve given by Turner¹⁰ the velocity-depth curve shown in Figure 1 was obtained. In this figure the abscissæ represent depth in kilometers and the ordinates the velocity, in km./sec. This curve closely resembles that obtained by Wiechert¹¹

⁹ Viz: $R/\rho = v_g^2$, and $K/\rho = v_p^2 - 4v_g^2/3$ which are obtained directly from the equations in the preceding footnote.

¹⁰ See Davison, *Manual of Seismology*, p. 145.

¹¹ *Nachr. Kgl. Ges. Wiss. Göttingen*, 1907, pp. 415-549.

and by Knott.¹² The velocity of both kinds of waves increases rapidly at first, and then steadily and almost linearly until a depth of 1,600 km. is reached, after which the velocity, although nearly constant, shows a tendency to fall off, especially at about 3,000 km. As will be shown below, when the density at various depths is known, these curves can be converted into compressibility-depth and rigidity-depth curves.

DENSITY CHANGE DUE TO COMPRESSION

We shall next use the above results to determine to what extent the higher density of the interior of the earth may be due to compression alone. The decrease in volume caused by pressure at great depths can not be calculated from the *measured* compressibility of rocks, even if the pressure were known, because the compressibility decreases with the pressure, which at a depth of only a few hundred kilometers is far beyond the range of laboratory measurement. But fortunately, the velocity of transmission of earthquake waves yields information as to the variation of compressibility ($1/K$) with depth. The values of K/ρ at various depths have been calculated from the earthquake velocities (see footnote on p. 245), and the results shown in column 4 of Table 1. Now, it is reasonable to suppose that from this information concerning compressibility it would be possible to determine the aggregate diminution in volume at a given depth on the supposition of a homogeneous earth whose central density is made high by compression and not by a change of composition. An equation connecting these quantities has been derived,¹³ and used

¹² Proc. Roy. Soc. Edinburgh, 39, 167. 1918.

¹³ The equation is derived as follows:

In general,

$$\frac{dp}{dr} = -g\rho = -\frac{6.66 \times 10^{-8} m\rho}{r^2}$$

where g is the acceleration of gravity and p is the pressure at distance r from the center; and m , the mass of the sphere of radius r , is obtained from the relation

$$m = 4\pi \int_0^r \rho r^2 dr \quad A$$

Now the first equation may be written $\frac{dp}{d\rho} \cdot \frac{d\rho}{dr} = -\frac{6.66 \times 10^{-8} m\rho}{r^2}$

but, on the assumption of homogeneity, $\rho \frac{dp}{d\rho} = K$, by definition.

Therefore, by division

$$\frac{d \ln \rho}{dr} = -\frac{6.66 \times 10^{-8} m\rho}{r^2 K}$$

or, \bar{r} being the mean radius of the earth and $\bar{\rho}\bar{r}$ the surface density,

$$\ln \frac{\rho}{\bar{\rho}} = - \int_{\bar{r}}^r \frac{6.66 \times 10^{-8} m\rho}{r^2 K} dr, \text{ which is the desired expression.} \quad B$$

The density-depth relation is obtained from this equation by approximation and repeated graphical integration. First, the density at various levels is assumed (consistent, of course, with the known average density of the earth). The quantity, ρr^2 , is then plotted against r , and m found by graphical integration of equation A. Next, the quantity, $m\rho/r^2K$, is plotted against r , and ρ as a function of r determined according to equation B by another graphical integration. This first approximation for ρ is used to calculate a new curve for m , which in turn yields a second approximation for ρ . It turns out that the convergence is very rapid, so that with almost any initially assumed values of the density three successive integrations are sufficient.

to calculate the increase of density with the earth due to compression alone. In the calculation of density changes by this equation the principal uncertainty lies in the choice of the surface density.

TABLE 1.—*First step in calculation of the change of density due to pressure at various depths*

r 10 ⁸ cm.	ρ Laplace	m 10 ²⁷ gram	$\frac{K/\rho}{\left(\frac{\text{cm.}}{\text{sec.}}\right)^2} \times 10^{12}$	A	$10 \frac{\rho'}{3}$	ρ'
6.37	3.00	5.98	0.299	2.86	0	3.00
6.00	3.61	5.39	0.446	2.24	0.102	3.32
5.50	4.44	4.56	0.651	1.54	0.191	3.63
5.00	5.27	3.86	0.901	1.14	0.261	3.89
4.50	6.08	2.92	1.001	0.96	0.313	4.10
4.00	6.86	2.18	1.001	0.91	0.359	4.29
3.50	7.58	1.55	1.001	0.84	0.402	4.48
3.00	8.25	1.02	0.890	0.85	0.444	4.68

The values in column 2 are obtained from the equation $\rho = 10.25 \frac{\sin 3.726 \times 10^7 r}{3.727 \times 10^7 r}$

The values in column 3 are obtained by integration of equation A, footnote 13, using the above values for ρ .

K/ρ in column 4 equals $0.01 (v_r^2 - \frac{4}{3}v_{44})$.

A equals $\frac{6.66 \times 10^{-27} m \rho}{r^2 K} \times 10^7$ using the values in the previous columns.

The sixth column is obtained from the fifth by integration of equation B, footnote 13, and yields the values of ρ' in the last column.

Table 1 shows the first step of such a calculation, the initially assumed values of ρ being those given by Laplace's law, with a surface density 3. From this first step alone it is evident that Laplace's distribution of density is impossible if the condition of homogeneity were fulfilled. In other words, the density according to Laplace increases faster than can be accounted for by compression alone.

The final density curves for two different assumed surface densities (3 and 3.5) are shown in Figure 2. The proper value to take for the initial density (i. e., for the effective surface density) is difficult to determine. It has been placed all the way from 2.7 to 3.7 by various investigators. It is generally agreed that although the average density of surface rocks is from 2.7 to 2.8, corresponding to granite or granodiorite, nevertheless the granitic layer is relatively few miles deep (say 5 to 20); and that underneath this very thin skin of granitic (and sedimentary) rocks lies a more basic material such as gabbro or even pyroxenite or peridotite.

For the moment it will be sufficient to note in figure 2 the density curves with two initial densities, 3 and 3.5, corresponding respectively to average gabbro and to dense peridotite. Although the calculation was carried only to a depth of 3,400 km., this limit being set by the seismologic data, it is clearly evident that the density is not increasing fast enough to make the mean density of the earth equal to 5.5.

For the two assumed surface densities the average density below 3,400 km. would be 15 and 20, respectively—obviously much too high to be reached by any reasonable extrapolation of the density curves. The high central density demanded by the comparatively low density shown in Figure 2 may be considered a consequence of the fact that the core of radius 3,000 km., has only one-ninth of the volume of the earth, whereas 0.3 to 0.4 of the mass remains to be accounted for.

It is therefore *impossible to explain the high density of the earth on the basis of compressibility alone*. The dense interior can not

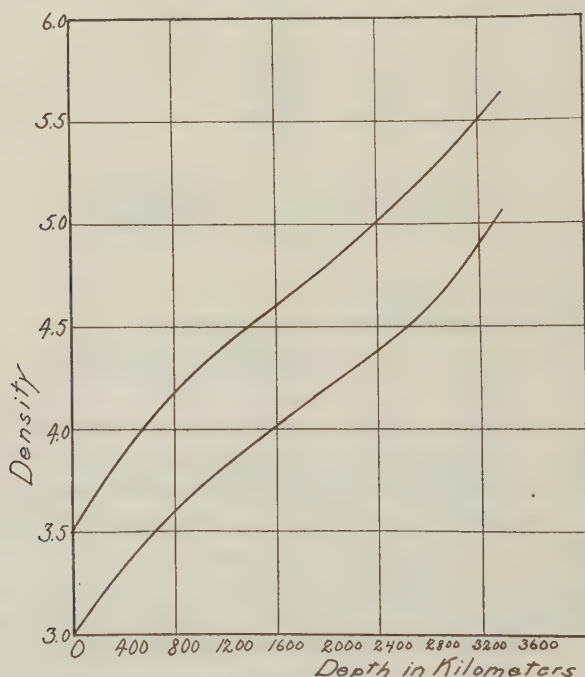


FIG. 2.—For two initial densities, 3.0 and 3.5, these curves show the change of density due to compression alone. The values are obtained from the variation of compressibility, which in turn is determined from the earthquake velocity-depth curve

consist of ordinary rocks compressed to a small volume. We must, as a consequence, fall back upon the only reasonable alternative, namely, the presence of a heavier material, presumably some metal, which, to judge from its abundance in the earth's crust, in meteorites, and in the sun, is probably iron. We thus arrive at the conclusion accepted by the majority of geophysicists, but, in addition, we have here (1) a quantitative estimate of the increase of density due to compression alone, and (2) *direct* evidence of the presence in the interior of the earth of a dense material such as iron.

THE ELASTIC CONSTANTS OF TYPICAL ROCKS

The elastic properties of a series of rock types are shown in Table 2, which is taken (with slight changes) from a previous paper by the authors.¹⁴ The compressibilities are based on direct measurements in the laboratory. From the compressibility is calculated the rigidity, and also the velocities with which earthquake waves are transmitted through the given kind of rock.

EFFECT OF TEMPERATURE

This is a disturbing and uncertain factor. From the known temperature gradient at the surface it follows that the temperature at 100 km. depth must be considerably above the melting point of ordinary rocks; and it seems unlikely that the central temperature can be less than several thousand degrees. The effect of this high temperature on the density is not easily estimated, and might conceivably be very large, but it so happens that the problem is simplified by the fact that at high pressures the expansion coefficient becomes less than at low pressures. Now, the pressure halfway down to the center of the earth is more than a million atmospheres, and it is not at all improbable that at this pressure the total thermal expansion and the effect of temperature on elastic constants would be relatively small. For the present, at any rate, we shall ignore the effect of temperature, but with the belief that it is a minor factor.

¹⁴ Adams and Williamson. Journ. Franklin Inst., 195, 520. 1923.

TABLE 2.—*Compressibility and rigidity of typical plutonic rocks at high pressures; and the velocity of earthquake waves as calculated from the elastic constants*

Rock	Suggested average composition (by volume)								Pres- sure mega- bars	Elastic constants				Densi- ty, ρ	Velocity of seismic waves km./sec		Rock
	Quartz	Ortho- clase	Ande- sine, Ab ₂ An ₁	Labra- diorite, Ab ₁ An ₂	Biotite	Amphi- bole	Augite	Hyper- sthene	Olivine	Meta- lic iron	Com- pressi- bility, $\beta \times 10^6$	Bulk modu- lus, $K \times 10^{-6}$	Rigid- ity, $R \times 10^{-6}$		Longi- tudinal (P)	Trans- verse (S)	
Granite	30	65			5						2.11	0.47	0.26	2.61	5.6	3.1	Granite.
Granodiorite	11	20	52		10	7					1.85	0.54	0.29	2.66	5.9	3.3	Granodiorite.
Syenite		90			5	5					1.82	0.55	0.30	2.69	5.9	3.3	
											1.62	0.62	0.34	2.73	6.2	3.5	
											1.86	0.54	0.29	2.61	5.9	3.3	Syenite.
											1.64	0.61	0.33	2.66	6.3	3.5	
Diorite			80		5	15					1.61	0.62	0.34	2.74	6.2	3.5	Diorite.
											1.45	0.69	0.37	2.78	6.5	3.7	
Gabbro				50			40	10			1.20	0.83	0.45	3.05	6.9	3.9	Gabbro.
											1.12	0.89	0.48	3.08	7.1	4.0	
Pyroxenite.							50	50			1.03	0.97	0.53	3.40	7.0	3.9	Pyroxenite.
											0.96	1.04	0.57	3.44	7.2	4.1	
Peridotite								50	50		0.98	1.02	0.55	3.40	7.2	4.0	Peridotite.
											0.91	1.10	0.60	3.44	7.4	4.2	
Dunite									100		0.94	1.06	0.58	3.38	7.3	4.1	Dunite.
											0.94	1.14	0.62	3.41	7.6	4.3	
Pallasite									50	50	0.76	1.31	0.71	5.65	6.3	3.6	Pallasite.
											0.72	1.39	0.76	5.69	6.5	3.7	
Siderite										100	0.59	1.69	0.92	7.9	6.1	3.4	Siderite.
											0.56	1.79	0.97	7.9	6.2	3.5	

PREVIOUS THEORIES OF DENSITY DISTRIBUTION IN THE EARTH

Laplace's distribution, already mentioned, should perhaps best be regarded as an empirical relation connecting density with depth, and should not be taken to imply anything concerning the cause of the increased density. The law of Laplace has been criticized because it requires too low a surface density in order to yield the correct value for the moment of inertia. Darwin¹⁵ suggested a different density law with a surface density of 3.7. He held that the ordinary rocks on the outside of the earth were a mere shell, to be considered separately, and that the density immediately beneath should be taken as the starting point.

The earlier pictures of the earth's interior involved the tacit assumption that the composition of the deeper parts was the same, or practically the same, as at the surface. According to this view, the earth was a huge ball of granite, chemically homogeneous, although possibly molten at the center. But following what might be called the granitic era of geophysics, the belief arose that the center of the earth might be quite unlike the rocks which we find at the surface and in our shallow excavations. More than 50 years ago Dana¹⁶ discussed the possibility of the earth being made up of a central iron core surrounded by silicate rock. Later, Weichert¹⁷ elaborated this hypothesis and postulated a core of density 8.4 within a stony shell 1,500 km. thick and of density 3.4. His arrangement¹⁸ fits both the mass and moment of inertia of the earth very well, and the transition point from rock to metal at 1,500 km. is in fair agreement with the sudden change of direction of the curve of earthquake velocities shown in Figure 1; but it takes no account of the density due to compression, and fails to explain why there should not be an actual discontinuity at the transition point. At moderate pressures the velocity in basic rocks is notably higher than in iron,¹⁹ and at very high pressures this difference will probably increase rather than decrease. Moreover, as may be seen in Figure 1, the velocity beyond 1,600 km. changes very little—contrary to what might be expected of a *homogeneous* mate-

¹⁵ G. H. Darwin. Proc. Roy. Soc. 1883.

¹⁶ J. D. Dana. Manual of Geology. 1873.

¹⁷ Nachr. Kgl. Ges. Wiss. Göttingen. 1897, p. 221. Phys. Z. 11, 294. 1910.

¹⁸ It may be noted that on the assumption of a core and a shell each of uniform density the radius and density of the core may be calculated from the known mass and moment of inertia and an assumed outer density by the two equations:

$$\rho_a - \rho_s = x^3 (\rho_1 - \rho_2)$$

$$\rho_m - \rho_s = x^5 (\rho_1 - \rho_2)$$

In which ρ_a is the mean density, ρ_m is the density of a homogeneous sphere of moment of inertia equal to that of the earth, ρ_1 is the density of the core, ρ_2 that of the shell, and x the ratio of the radius of the core to that of the earth. Thus, if the density of the outer layer is 3.00, its thickness must be 1,300 km. and the density of the core is 8.03; and if the outer density is 3.40, the thickness of the shell would be 1,600 km. and the central density 8.45.

¹⁹ See Table 2.

rial under a constantly increasing pressure. It may be argued that the effect of temperature in this region may decrease the elastic constants and hence also the velocity. But on any hypothesis the temperature is not increasing rapidly as far down as this, and it seems highly improbable that increasing temperature would have sufficient effect on both the rigidity and the bulk modulus so that with increasing depth the two velocities would remain nearly constant over a range of 1,400 km. The constancy of the velocities is truly a remarkable feature and, as will appear below, furnishes an important clue for the solution of the problem of the earth's interior. In recent times Goldschmidt²⁰ has postulated an arrangement of the matter within the earth as follows: (1) An outer silicate layer 120 km. thick and of density 2.8; (2) a layer of dense silicates (eclogite) extending to 1,200 km. depth with density varying from 3.6 to 4; (3) an intermediate zone of sulphides and oxides of density 5.6 and extending to 2,900 km.; and (4) a central core of nickel-iron having a density about 8. The average density of this arrangement is very close to the accepted value, and the moment of inertia, although 3 per cent too low, can be considered in fair agreement. Zoeppritz, Geiger, and Gutenberg,²¹ and Mohorovičić,²² and others, have adduced evidence in favor of the existence of various shells or layers in the earth, but the arrangement which most nearly resembles that which we shall describe in the next section is that given by Gutenberg²³ in a paper which came to our attention after our paper was written. He obtains a density-depth curve which, like ours, consists of four parts. The starting point of his derivation is the assumption that the core is of constant density 2.3 times that of the layer above it, which also is of constant density. He concludes that the density of the layer extending from 60 km. to 1,200 km. depth varies from $3\frac{1}{2}$ at the top to $4\frac{3}{4}$ at the bottom. In this respect his estimate of the density change within the earth is strikingly like that which we shall now describe, although ours is based on the change of density due to compressibility and involves assumptions quite different from those of Gutenberg.

PROPOSED DISTRIBUTION OF MATTER WITHIN THE EARTH

OUTERMOST LAYER

The average density of the igneous rocks²⁴ at the surface is about 2.8. Allowing for a small amount of sedimentary rock, let us take the surface density as 2.7. The density and basicity of the rocks

²⁰ V. M. Goldschmidt. *Z. Elektrochem.*, 28, 411. 1922.

²¹ *Nachr. Kgl. Ges. Wiss. Göttingen.* 1912, p. 121.

²² S. Mohorovičić. *Beitr. z. Geophysik*, 13, 217-240. 1913; 14, 188-198. 1914.

²³ B. Gutenberg. *Phys. Zeit.*, 24, 296-299. 1923.

²⁴ H. S. Washington. *Bull. Geol. Soc. Am.*, 33, 388. 1922.

must increase with depth, although the increase is not necessarily regular. Probably the outer 10 to 20 km. has the average composition of a granite or a granodiorite. From the seismographic records of the Oppau explosion, Wrinch and Jeffreys²⁵ find the velocity of the longitudinal waves to be 5.4 km./sec., and Mohorovičić²⁶ by analysis of the records of near earthquakes concludes that the velocity from the surface to a depth of 60 km. is nearly constant and equal to 5.8 km./sec. The data given in Table 2 enable us to use these observations to determine the composition of the outermost layer and to compare it with the thin surface film accessible to direct examination. Theoretically the surface velocity can be obtained from the initial slope of the ordinary time-distance curve, but on account of the scarcity of reliable observations for near earthquakes the extrapolation of the surface velocity back to zero distance is unsatisfactory, and, moreover, as emphasized by Wrinch and Jeffreys, the usual uncertainty regarding the depth of focus would vitiate the results at short distances. From Turner's table the "surface" velocity of the longitudinal waves seems to be about 7.1 km./sec.—between the values for pyroxenite (7) and for peridotite (7.2), and distinctly higher than that for gabbro (6.9). According to Mohorovičić, the velocity of the longitudinal waves suddenly changes from 5.8 to 7.9 km./sec. at a depth of 60 km. From Table 2 it may be seen that the velocity in granite is 5.6 km./sec. The seismologic data, therefore, although none too satisfactory, seem clearly to indicate that the crust of the earth is largely granitic in character, but that at a depth of 100 km. or less, basic material becomes predominant.

We propose, somewhat arbitrarily, to take 60 km. for the thickness of the layer in which the rocks change from acid to basic. Whether or not the change is gradual is a question to be decided at some future time. The lower limit of this layer may or may not be identical with the depth of isostatic compensation. From gravity measurements in mountainous regions this depth is placed by Bowie²⁷ at 96 km., but from the data over the whole United States he places it at 60 km. Washington,²⁸ moreover, finds the average density of various regions on the earth to harmonize with the average elevation on the basis of isostatic compensation at a depth of 59 km. In any case this layer has a volume of only a few per cent of the total volume of the earth, and its thickness has little effect on the density distribution of the earth as a whole. The basaltic substratum, postulated by Daly, Wegener, and others, and of great

²⁵ Dorothy Wrinch and Harold Jeffreys. Roy. Astr. Soc., M. N., Geophys. Suppl. 1, pp. 15-22. 1923.

²⁶ *Loc. cit.*

²⁷ W. Bowie. U. S. Coast and Geod. Survey, Sp. Publ. No. 40, 133. 1917.

²⁸ H. S. Washington. *Op. cit.*, p. 405.

importance in interpreting the geology of the earth's crust, is here merely an incidental feature in the transition from granitic to ultrabasic material.

BASIC LAYER

Referring again to Figure 1, one may note that the earthquake velocity curves run regularly and almost linearly from near the surface to about 1,600 km. depth. It is natural to assume that this region then is a more or less homogeneous material, the bulk modulus and rigidity of which increase regularly with pressure. From reasons given below it is probable that the normal density (i. e., the density at low pressures) of this material is 3.3, which corresponds to 3.35 at a depth of 60 km. The density at other depths may be obtained by interpolation between the two curves of Figure 2. Thus, at 1,600 km. depth the density has increased by compression to 4.35. The normal density 3.3 corresponds to a pyroxenite or a peridotite. Throughout this whole region the temperature must be very high, and it is possible that a part of this layer is at a temperature above its melting point, its high rigidity being maintained by pressure.²⁹ Both the density and the earthquake velocity will probably be somewhat smaller in such a glassy material than in a crystalline layer of the same composition, but the difference can hardly be great enough to nullify the evidence in favor of an ultrabasic layer.

It has been suggested that meteorites should have the same average composition as that of the earth or of any other part of the solar system. Now this average composition³⁰ (due account being taken of the proportion in which stony and metallic meteorites are seen to fall) corresponds to: Olivine, 35; pyroxene, 42; anorthite, 4; troilite, 5; nickel-iron, 13. The silicate portion is principally an olivine-pyroxene mixture and thus is essentially a peridotite, and should have nearly the same density and compressibility as that postulated for the basic layer.

PALLASITE LAYER

As already noted, a remarkable feature of the earthquake velocity curves (fig. 1) is the small amount of change beyond a depth of 1,600 km. From compressibility measurements the velocity of the longitudinal waves in iron at moderate pressures is 6.1 km./sec., whereas the velocity in peridotite is 7.2. At high pressures the difference will probably be greater. This circumstance immediately suggests that the nearly constant velocity below 1,600 km. may be

²⁹ Cf. R. A. Daly. *Igneous Rocks and their Origin*. (New York, 1914.) p. 172. *Am. Journ. Sci.*, 5, 349-371. 1923.

³⁰ Cf. O. C. Farrington. *Field Columbian Museum, Geol. Ser.*, Vol. 3, Publ. No. 120: 211-13. 1911. W. D. Harkins. *Journ. Am. Chem. Soc.* 39: 864. 1917.

due to a gradually increasing amount of metallic iron mixed with the siliceous rock. The normal tendency for pressure, and hence depth, to increase the velocity is thus offset by the admixture, in gradually increasing amount, of iron (or nickel-iron).

The material in this region may be thought of as resembling certain meteorites consisting of a heterogeneous mixture of silicates and metallic iron, which is called pallasite. The lower limit of this zone of incomplete segregation is thought to lie at about 3,000 km. depth where the velocity shows distinct evidence of falling off.

CENTRAL METALLIC CORE

The remaining part of the earth consists, beyond reasonable doubt, mainly of iron or nickel-iron with density appropriate to the conditions of pressure (and of temperature) existing in the central region. This density should increase toward the center, but by a relatively small amount.

Now, if we assume (*a*) that the density in the surface layer varies linearly with depth from 2.7 to some chosen density ρ_s at the top of the basic layer, (*b*) that in this basic layer the density change can be calculated by interpolation between the two curves of figure 2, (*c*) that in the pallasite layer the density changes linearly with depth (the simplest assumption), and (*d*) that in the central core the density changes parabolically,³¹ the fact that the distribution must satisfy the known mass and moment of inertia of the whole earth allows us to solve two simultaneous equations and find the density distribution in the pallasite layer and in the central core. If this calculation be carried out for various values of ρ_s , it is found that ρ_s must be close to 3.35 in order to yield a reasonable density variation in the central core. The value 3.45 demands that in the core the density *decrease* with depth. On the other hand, the value 3.25 leads to an unreasonably high density at the center. For this reason the density at the top of the basic layer has been taken as 3.35, corresponding, as stated above, to a normal density 3.3 and to a density 4.35 at 1,600 km. The density of the iron would then be 9.5 at 3,000 km. and 10.7 at the center.

These various considerations lead us to adopt more or less tentatively, the following arrangement of material within the earth: (1) An outer layer 60 km. (about 35 miles) thick³² in which the mate-

³¹ That is, according to the relation: $\rho = k_1 + k_2 r^2$, k_1 and k_2 being constants. This is the simplest assumption compatible with the necessary condition that the rate of change of pressure with distance is zero at the center.

³² This applies more particularly to continental areas. In the Atlantic Ocean, and especially in the Pacific Ocean, the thickness of the outer layer is probably much less than 60 km.

rial changes more or less gradually from granitic to something more basic than a gabbro; (2) a shell extending to a depth of 1,600 km., consisting of peridotite, that is, mainly of iron-magnesium silicates and having a normal density 3.3 and a density at 1,600 km. of 4.35; (3) a shell of pallasite reaching to 3,000 km. below the surface, in which silicate rock is gradually replaced by metallic iron (or nickel-iron) not yet completely segregated, the density in this shell changing gradually from 4.35 to 9.5; and (4) below this layer of pallasite a central core of nickel-iron of nearly constant density—varying from a little below to a little above 10. The existence of other lay-

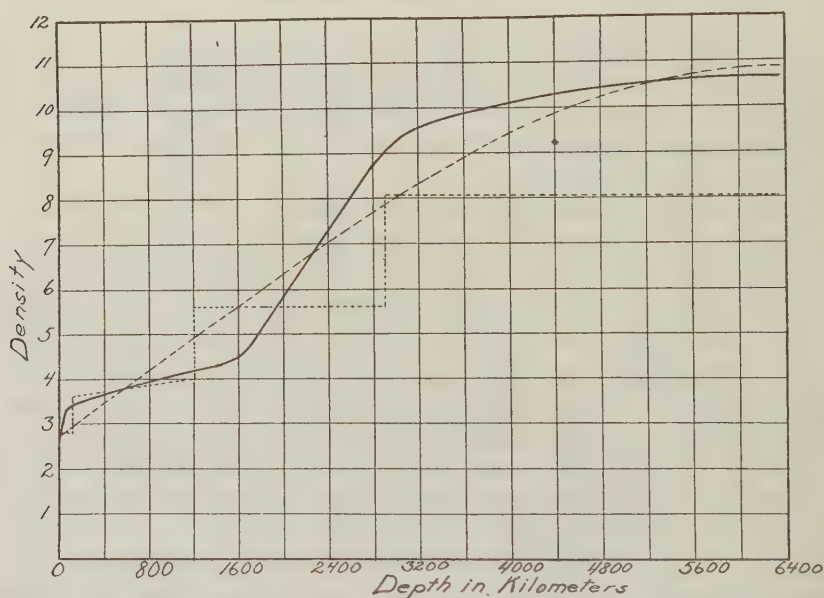


FIG. 3.—The density of the earth at various depths according to the present estimate (full-line curve). For comparison Goldschmidt's distribution (dotted lines), and the density law of Laplace (broken line) are included

ers or of other discontinuities is neither affirmed nor denied. The proposed distribution of material merely attempts to harmonize certain known facts regarding the mass and moment of inertia of the earth, the velocities of earthquake waves, and the compressibilities of rocks. It is put forth more as a basis for future speculation than as a definite and final arrangement.

The distribution here described is shown graphically in Figure 3 (full-line curve). At the boundary between the various zones the corners are arbitrarily slightly rounded. This diagram also contains, for comparison, a plot of Goldschmidt's distribution (dotted lines), and the density according to Laplace's law (dashed line) with surface density 2.7.

It is truly remarkable that Laplace's equation, which can be regarded merely as an empirical relation, should yield values of the density so close to those obtained in what we believe is a more rational way. The fact that Laplace's law leads to the right moment of inertia, of course, indicates that the densities obtained by it may be correct to at least a rough approximation, and accounts for its general use among geophysicists. The assumption involved in its derivation is, however, by no means warranted.

Figure 4 is intended to illustrate the segregation of iron toward the center and the fringe of pallasite surrounding the iron core.

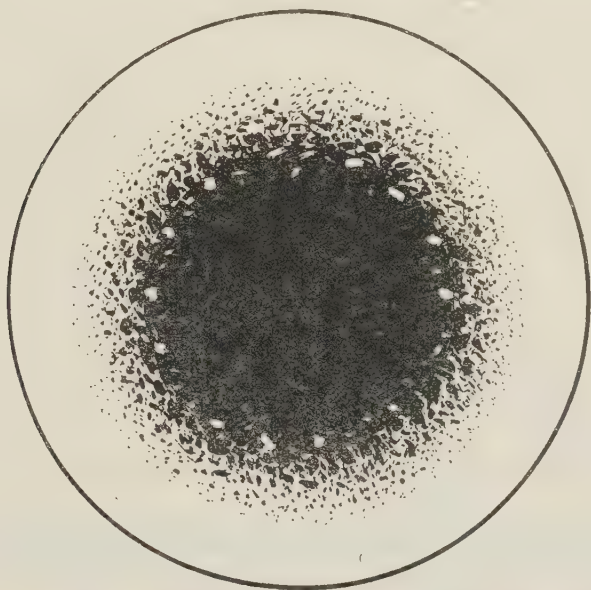


FIG. 4.—Diagram intended to suggest the segregation of metallic iron toward the center, and the zone of pallasite (mixture of iron and silicates) surrounding the central core

The depth of the surface layer—60 km.—is shown to scale by the thickness of the outer circular line.

COMPRESSIBILITY, RIGIDITY, AND BULK MODULUS

By combining the earthquake velocities given in Figure 1 with the densities given in Figure 3, the elastic constants of the material within the earth at various depths may readily be obtained.³³ The values of the rigidity and bulk modulus have been calculated and are shown graphically in Figure 5. It is very interesting that these curves are comparatively smooth; they show no pronounced irregularities or sudden changes of direction, such as are shown by the

³³ The equations used are: $E = \rho v_s^2$, $K = \rho (v_p^2 - 4v_s^2/3)$.

density and velocity curves from which they are derived. This means that from the surface to a depth at least halfway down to the center the elasticity of the material increases regularly and steadily in spite of the fact that the material changes in character, being silicate rock near the surface and metallic iron farther down.

At great depths the bulk modulus is very great, and therefore the compressibility, which is the reciprocal of the bulk modulus, is very small. Thus at a depth of 1,600 km. the silicate is nearly as incompressible as diamond, which is the least compressible of any known substance.

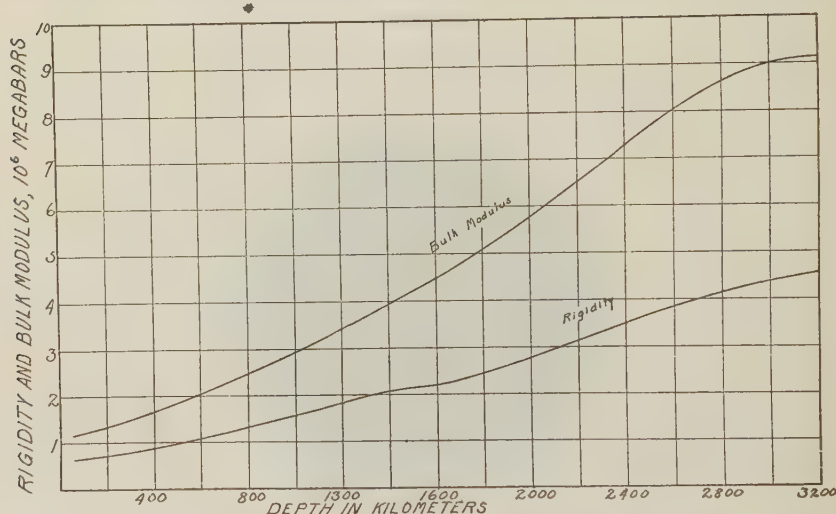


FIG. 5.—The rigidity and bulk modulus at various depths below the surface as calculated from the densities and earthquake velocities. The rigidity is the resistance to deformation, and the bulk modulus is the resistance to compression and is also the reciprocal of the compressibility

The rigidity also is very high in the interior of the earth. From the fact that the rigidity of steel is about 0.9 in the units used in Figure 5, it may be seen that except near the surface the rigidity of the earth is greater than that of steel. The rigidity is equal to 0.9 at about 400 km. depth and rises to five times this amount at 3,000 km. depth. Measurements⁸⁴ based on the tidal deformation of the earth indicate that the effective rigidity of the earth for such deformations is 0.86, which according to Figure 5 is the average rigidity of the outer 800 km., or 500 miles. If, then, it be the outer 800 km. which takes part in tidal deformations, the agreement between the two entirely different methods of determining rigidity would be complete.

⁸⁴ A. A. Michelson. *Astrophys. Journ.* 39, 105-138. 1914.

PRESSURE IN THE EARTH

The pressures corresponding to the present density distribution were obtained by graphical integration³⁵ from the densities shown by the full line in Figure 3. A graph of the pressure at various depths within the earth is shown in Figure 6. At the center the pressure is 3.18 millions of megabars (practically 3 million atmospheres), and is remarkably close to the value 3.08 million megabars, obtained from Laplace's equation with a surface density 2.7.

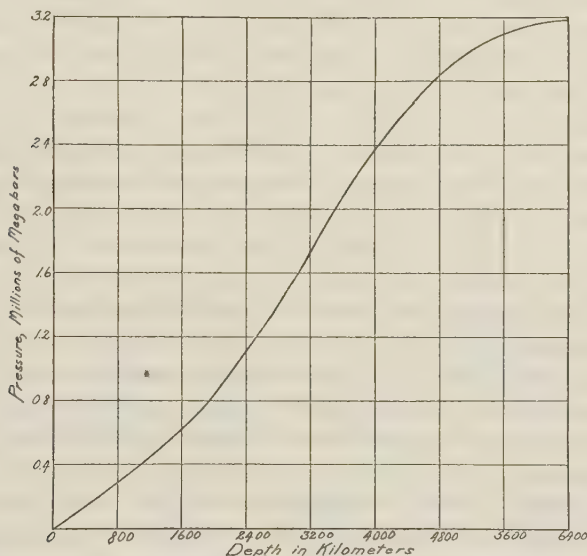


FIG. 6.—Pressure as a function of depth, derived from the full line curve of Figure 3. A megabar is about one atmosphere. More exactly, 1 megabar=0.987 atm.

CONCLUDING REMARKS

In conclusion we refer to the following passage from the Annual Report of the Director of the Geophysical Laboratory:³⁶

Both science and story have left the interior of the earth virtually a closed book. Imaginative writers have forecast many of the conquests of the sea and of the air and of the regions beyond, but the interior of the earth remains inaccessible to them; scientific effort has often been consciously and even eagerly directed toward it, but has revealed scarcely more. The distance

³⁵ The equation is:

$$p = \int_0^r \frac{6.66 \times 10^{-8} m \rho}{r^2} dr$$

in which m is obtained by another graphical integration of the equation:

$$m = 4\pi \int_0^r \rho r^2 dr$$

³⁶ Dr. Arthur L. Day, director. The report appears in the Year Book of the Carnegie Institution of Washington, No. 22 (1923).

from the surface to the center of the earth is some 4,000 miles, of which hardly more than a mile has been actually explored. What properties or what substances even a few more miles might reveal is a matter for inference alone, inference for the most part with a very inadequate if not an insecure foundation of fact.

The physical properties and the chemical composition of the interior of the earth are not yet amenable to precise measurement. But, starting from recent determinations of the compressibility of rocks, in conjunction with the known velocities at which earthquake shocks are transmitted through the earth, it is possible to draw important conclusions concerning the nature of the material far within the earth. For example, we can estimate the pressure at a given depth, and we can tell approximately the amount by which the density of rocks is raised by these enormous pressures. We know definitely that rocks can not be squeezed into a volume so small that their density would be sufficient to account for the high density of the earth as a whole. Beyond reasonable doubt, the earth has a metallic core of iron, or nickel-iron, the diameter of this core being about one-half that of the earth. Bordering the iron core, moreover, there is a fringe of mixed iron and silicate, and surrounding this is a silicate shell. We can determine with fair accuracy the rigidity of the material at a given depth within the earth, and can assure ourselves that, except near the surface, the rigidity is considerably greater than that of steel. Finally, as to chemical composition, the earth, except for the surface layer—which in comparison with the whole earth is of negligible volume—is composed mainly of metallic iron and iron-magnesium silicates. Accordingly, the earth consists almost entirely of four elements: Iron, magnesium, silicon, and oxygen.

DIAMOND-BEARING PERIDOTITE IN PIKE COUNTY, ARKANSAS¹

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[With 3 plates]

INTRODUCTION

The diamond mines of Arkansas, which have produced several thousand stones, are the only such mines on the North American continent, though a few diamonds have been found from time to time at other places in the United States and at some places in Canada.

Most of the diamonds found in North America outside of Arkansas have been obtained from gold placers in the Piedmont region of the Carolinas and Georgia, from placers in the Western States, especially California, and from glacial deposits in regions as widely separated as Nova Scotia and Wisconsin. All these stones were found far from their sources, for placers are composed of stream-transported material and glacial deposits consist of ice-transported rock débris. The material in the placers has been carried from rather well-known regions in which it seems unlikely that rich diamond-bearing rocks occur. The diamonds found in these placers were probably derived from dunite or serpentine, rocks that are related to diamond-bearing peridotites but that contain very few if any diamonds. The diamonds found in the glacial deposits, like the granitic boulders, were carried from their parent ledges in Canada by the continental glaciers that advanced southward into the northern United States. It has therefore been surmised that the rocks at some places in Canada might be rich in diamonds, but if such a diamond deposit exists it is lost in the vast barren lands of the North—more hopelessly lost than the most fanciful “lost gold mine” of our own great West.

The diamond deposits of the world may be grouped into two principal classes. Those in Brazil, India, and Australia and some of those in Africa are in placers, where the stones have been more or less concentrated by wind and water; but the largest deposits in

¹ Abstracted and reprinted by permission from *Economic Geology*, vol. 17, December, 1922.

South Africa and those in Arkansas are in solid rock or in soft residual material overlying it. All such rocks in both South Africa and Arkansas belong to the variety known as peridotite, which in both regions fills narrow volcanic craters and necks.

Peridotite contains comparatively small proportions of silica and alumina but much magnesium and iron. It invariably contains the mineral olivine, but usually includes a rather large proportion of brown mica and small proportions of other minerals. It is the only rock that is known to be the original source of paying quantities of diamonds.

The peculiar type of diamond-bearing peridotite that occurs in South Africa has been called kimberlite, after the famous Kimberley mine. The diamond-bearing rock of Arkansas, which is similar, is also known as kimberlite.

DISCOVERY

On August 1, 1906, John W. Huddleston discovered diamonds on his property on Prairie Creek, $2\frac{1}{2}$ miles south-southeast of Murfreesboro, Ark. One stone was submitted to the Mermod, Jaccard & King Jewelry Co., of St. Louis, and a little later other stones were examined by George F. Kunz, a gem expert, of New York. The stones came from an area of weathered peridotite that had long been recognized by geologists as similar to the diamond-bearing peridotite of South Africa, so it was evident that an original source of diamonds had been discovered in North America.

The existence of peridotite in this part of Arkansas was known as early as 1842. The first detailed report describing the geologic relations and nature of the peridotite was published in 1889 by John C. Branner, State geologist of Arkansas, and R. N. Brackett. Branner, in an article published in 1909, states that at the time of his field examination, in the late eighties, he recognized the peridotite as the kind of rock in which diamonds occur in South Africa. He spent many hours on his hands and knees looking for diamonds in the gullies and over the bare surfaces of the decomposed rock, but he did not dare mention at that time his suspicion that diamonds might be found in that region, because any such suggestion would have added fuel to the wild mining excitement that was then raging farther north in Arkansas.

The finding of the diamonds by Huddleston led to a search which resulted in the discovery of three other exposures of peridotite.

LOCATION

Peridotite is exposed in four areas, all near Murfreesboro, Pike County, Ark., three of which have produced diamonds. The exposure first discovered lies $2\frac{1}{2}$ miles south-southeast of Murfrees-

boro, near the confluence of Prairie Creek with Little Missouri River, and is known as the Prairie Creek peridotite area. Several thousand stones, ranging in weight from a small fraction of a carat to 40.23 carats, have been found, most of them coming from the Ozark, Mauney, and Arkansas mines. The other exposures of peridotite are all within an area of 1 square mile, about 2 miles northeast of the Prairie Creek locality and 3 miles S. 75° E. of Murfreesboro. Two of these exposures, the Kimberlite and American areas, so named for the Kimberlite and American mines located on them, are in sec. 14, T. 8 S., R. 25 W.; the third, the Black Lick area, is near a locality known as the Black Lick, in the northwest corner of sec. 23, T. 8 S., R. 25 W. The Kimberlite and American areas have been prospected for diamonds and each has produced a small number of stones. The Black Lick area has been prospected less than any of the others and has thus far produced no diamonds.

These known areas of diamond-bearing peridotite are in the Gulf Coastal Plain, only a few miles south of its northern margin, beyond which lies the Ouachita Mountain region. The Ouachita region, which is 50 to 60 miles wide, extends from Little Rock, Ark., to Atoka, Okla., a distance of 200 miles. It contains numerous nearly eastward trending ridges, several intermontane basins, and a dissected Piedmont Plateau known as the Athens Plateau, which is 15 miles wide, lying between the Coastal Plain and the Ouachita Mountains. The surface features and also the geologic structure of this part of Arkansas are therefore very similar to those of the Central and South Atlantic States. The Gulf Coastal Plain, which corresponds to the Atlantic Coastal Plain, is bordered on the north by the Athens Plateau, which corresponds to the Piedmont Plateau. North of the Athens Plateau there are closely spaced parallel ridges of the Ouachita Mountains, which correspond in appearance and relative position to the Appalachian Mountains between eastern Pennsylvania and northern Alabama.

The Kimberlite, American, and Black Lick areas of peridotite are on a deeply channeled plateau that lies east of Little Missouri River. The Prairie Creek area adjoins the bottom lands of Little Missouri River and Prairie Creek.

The region in which the diamond deposits occur is sparsely populated except in the level or gently rolling upland and valley areas, where most of the tillable land occurs.

ROCKS ASSOCIATED WITH THE PERIDOTITE

The rocks associated with the peridotite are sedimentary and are of Carboniferous, Lower Cretaceous, Upper Cretaceous, and Quaternary ages. The Carboniferous rocks are shales and sand-

stones, which were compressed into close east-west folds near the middle of the Pennsylvanian epoch. Between this epoch and the Lower Cretaceous epoch they were greatly eroded and a peneplain was formed which beveled their upturned edges. This peneplain was submerged near Murfreesboro as well as in other areas during the Lower Cretaceous epoch, and upon it several hundred feet of gravel, sand, clay, and limestone, which comprise the Trinity formation, was laid down. Another period of erosion followed the Lower Cretaceous epoch. In consequence of this the next younger strata, the volcanic tuffs, gravels, sands, and clays of the Bingen formation, of Upper Cretaceous age, rest unconformably upon the Trinity formation. Both the Trinity and the Bingen have a dip of about 100 feet to the mile toward the south. Terrace and alluvial deposits of Quaternary age which consist of gravels and silts 25 feet thick or less occur along Little Missouri River and its larger tributaries.

Peridotite was intruded into the Carboniferous rocks and the Trinity formation. The Carboniferous sandstones have been changed to quartzites at places, and the clays of the Trinity formation have been vitrified for a few feet away from the peridotite.

CHARACTER OF THE PERIDOTITE

The peridotite in each of the four separate areas is similar. The area of peridotite near the mouth of Prairie Creek, which so far as known is larger than the others, presents much the best rock exposures and has produced practically all of the diamonds found up to the present time in Arkansas. Although this area comprises about 73 acres, the exposures of the hard unweathered rock cover not more than 12 acres, for the peridotite has weathered to a soft earth at many places and to a fairly soft rock at others. (See Pls. 1, 2, and 3.) The depth of the altered peridotite has not been fully determined, though drill holes have shown that it is at some places at least 205 feet. The surface soil that overlies it to a depth of 1 to 4 feet is black from the presence of organic matter and is known as "black ground."

The peridotite is divisible into three rather distinct types. One is a massive little-weathered rock that the miners call "hardebank," which was intruded and which solidified in place. Another is volcanic breccia that was blown out of the craters by violent explosive outbursts of volcanic activity. The third is a volcanic tuff of finer grained material that was deposited in about the same way as the breccia.

The hard unweathered massive rock, the "hardebank," is a porphyry containing large crystals of olivine (now partly altered to serpentine) and brown mica, inclosed in a finer grained groundmass

of brown mica, augite, and a small quantity of pervoskite, magnetite, and chromite.

The volcanic breccia is a consolidated aggregate composed of volcanic fragments ranging from dustlike material up to pebbles half an inch or more in diameter. The original minerals have been largely altered to serpentine, but the breccia is essentially similar in mineral composition to the "hardebank." The breccia is, however, diamond bearing, whereas the "hardebank" and the volcanic tuff appear to contain few if any diamonds. The diamonds constitute a remarkably small proportion of even the most productive rock. It is interesting to note that at the great Premier mine, in South Africa, where the yield is very accurately known, diamonds constitute less than 1 part in 12,000,000 of the peridotite. The breccia, being fragmental, has been much more thoroughly weathered than the massive "hardebank," and the products of the weathering are at most places a soft earth and at others a fairly soft rock. These weathered materials show many shades of green, blue, and yellow, and are known by the miners as "green ground," "blue ground," and "yellow ground."

The volcanic tuff was probably formed in the same way as the breccia, and the original minerals were probably similar. It has, however, undergone a different type of alteration; and though the breccia is now largely serpentine, the tuff contains much chlorite, which gives a distinctly blue color.

The volcanic eruptions that brought about the formation of the diamond-bearing beds differed from the more familiar type of volcanic eruption in that there was probably little extrusion of lavas, but the explosive force must have been stupendous. A pipelike crater was blasted through older rocks, and fragments of these rocks were mixed with the shattered peridotite, thus forming the volcanic breccia. The massive "hardebank" probably welled up into the throat of the crater and cooled there without producing notable flows.

RELATION OF THE PERIDOTITE TO THE OTHER IGNEOUS ROCKS OF ARKANSAS

The peridotite in Pike County is of the same age or nearly the same age as the other igneous rocks of Arkansas, which consist of nephelite, syenite, pulaskite, and related types of intrusive rocks and which occur in four small separate areas in the eastern part of the Ouachita Mountain region and in the northwest border of the Gulf Coastal Plain. One of these areas is in the Fourche Mountain region near Little Rock, Pulaski County, where the igneous rocks have yielded bauxite deposits; a second is near Bauxite, Saline County,

where there are other bauxite deposits; a third is at Magnet Cove, Hot Spring County, from which beautiful mineral specimens have found their way into most of the museums of the world; and a fourth is at Potash Sulphur Springs, Garland County. In addition to these areas, hundreds of dikes of igneous rock are found here and there through much of the eastern half of the Ouachita Mountain region.

AGE OF THE PERIDOTITE

The intrusion of the peridotite probably accompanied the diastrophic movements that produced the down warping of the Mississippi embayment early in Upper Cretaceous time.

Although the rocks of the four different exposures mentioned are not connected at the surface, the similarity of the material makes it seem very probable that they are of common origin. The three types of peridotite were apparently formed by three distinct volcanic outbursts, but they are so closely related that they probably mark successive stages in a single period of volcanic activity. The evidence so far obtained indicates that the igneous history of the region was probably as follows:

First, the massive peridotite, probably accompanied by explosions, was intruded into the Carboniferous and Lower Cretaceous rocks. Next, volcanic explosions broke into small fragments not only much of the massive peridotite but some of the Carboniferous shale and sandstone. In the area of peridotite near Prairie Creek the fragments ejected into the air were deposited in inclined layers which, in hardening, have formed a breccia. The layers dip 30° W. in the Ozark mine (pl. 2, fig. 2), 20° – 30° SW. at the apex of the Mauney mine, and 50° or more toward the north near the south side of the Arkansas mine. The fact that the layers thus dip toward the center of the exposure of peridotite near Prairie Creek strongly suggests that the vent or vents from which the fragments were ejected were near the center of the Prairie Creek area and that the fragments were deposited within the crater of a volcano.

A second group of explosions probably formed the tuffs of the area near Prairie Creek.

The peridotite is younger than the Trinity formation, which is of Lower Cretaceous age, as is shown by the high dip of the contacts between the peridotite and the nearly horizontal beds of the Trinity, by the metamorphism of the clay of the Trinity adjacent to its contact with the peridotite, and by the occurrence in the peridotite of fragments of clay and pebbles derived from the Trinity.

The peridotite is probably of the same age as the Bingen formation (Upper Cretaceous), though it may be older. This is shown by the fact that the lower beds of the Bingen contain at places

altered grains of serpentine and fragments of peridotite. That the peridotite is not younger than the Bingen is shown by the fact that the Bingen rests upon the peridotite at the American mine and at the Black Lick.

COMPARISON OF ARKANSAS AND SOUTH AFRICAN ROCKS

The peridotite of Arkansas is generally believed to be similar in character and mode of occurrence to that of South Africa, but the exact points of similarity have not been recorded. Wagner,² who has carefully studied the South African diamond deposits, says of them:

The pipes represent deeply eroded, funnel-shaped volcanic necks of the Maar type, which appear to have been formed by the violent explosive liberation at the earth's surface of highly compressed vapors and gases, emanating from a deep-seated, ultrabasic magma. They are occupied, as a rule, by nonvolcanic detritus derived from the shattering and comminution of the rocks pierced by the explosions, by fragmentary material derived from trituration of kimberlite [peridotite], and at greater depths by solid plugs of the later rock.³

Dealing first with the relationship of pipes to fissures, we have learned that the magma in its ascent appears invariably to have been guided to within a greater or less distance of the original surface by planes of structural weakness in the earth's crust. * * * The earliest eruptions appear to have been in the nature of mighty explosions, which resulted in blowing out of funnel-shaped apertures. The bulk of the material forcibly ejected during these outbursts no doubt fell back into the vents, which at one stage of their history may thus have been more or less completely occupied by nonvolcanic detritus. The relief of pressure occasioned by these earlier explosions must be assumed to have led to the ascent of the magma into the pipes, where it appears, as a rule, to have given rise, by successive eruptions, to a number of distinct columns of kimberlite [peridotite] and kimberlite tuff.⁴

The material that occupies the vents Wagner describes as follows:

It has been pointed out that in so far as the pipe filling is concerned, the rocks pierced by the explosions, the kimberlite magma, and the atmosphere have all contributed.⁵

We may divide * * * the foreign matter of the pipes into three principal groups—rock fragments derived from the adjacent pipe walls; xenoliths [included fragments] of rock which have been brought up from below; masses of rock which, to attain the position in which we now find them, must have fallen into the pipes from above.⁶

The pipe rock proper consists of kimberlite and of material derived from its brecciation, comminution, and decomposition.⁷

The microscope reveals the fact that among the products comprehended under the general term of blue ground three main varieties may be distin-

² Wagner, P. A., "The diamond fields of southern Africa," 1914.

³ Op. cit. p. 5.

⁴ Op. cit., p. 41.

⁵ Op. cit. p. 18.

⁶ Op. cit., p. 20.

⁷ Op. cit., p. 24.

guished. These are the true kimberlite tuff or kimberlite breccia, injection breccia, and decomposed kimberlite. * * * As greater depths are attained in the mines the products we have hitherto been dealing with, as one would naturally expect, are replaced in increasing measure by "hardebank," or kimberlite, the parent rock, to the trituration and decomposition of which they owe their origin.⁸

Wagner divides the diamond-bearing rocks of South Africa into two types, both of which occur as intrusives and as volcanic breccias. One of these is a "basaltic kimberlite," rich in olivine and poor in mica, and the other is a "mica peridotite." Both types are diamond-bearing in South Africa, but the first has produced most of the diamonds.

The quotations and abstracts given above, which outline very briefly the type of eruption and describe the diamond-bearing rocks of South Africa, serve as a basis for comparison with the diamond-bearing rocks of Arkansas. In South Africa work has proceeded to great depths—3,601 feet in the Kimberley mine—and the geologic relations are known in considerable detail, whereas in Arkansas only the surface of the ground has been scratched. Nevertheless rather striking points of similarity between the diamond-bearing rocks of South Africa and of Arkansas are evident.

The violence of the volcanic explosions by which the South African vents were produced and the extent to which the kimberlite and country rock were shattered and mixed together in the vents have been emphasized. In Arkansas the peridotite was evidently much shattered and the explosive violence brought to the surface Paleozoic rocks that lay far beneath the surface. Injection breccias that are composed of shattered country rock mixed with a small proportion of volcanic material and that have the characteristics of dikes have been identified in both areas.

In many of the South African vents recurring volcanic activity produced compound pipes that are formed of slightly different rocks and that even bear diamonds of dissimilar character. Petrographic studies have shown that in Arkansas there are at least three types of rock, only one of which carries diamonds in considerable quantity.

DIAMONDS

Nearly all the diamonds obtained from Arkansas have been found within the exposures of peridotite in the area near Prairie Creek and at the Kimberlite and American mines near by, though a very few diamonds have been found along streams that have washed them from these areas. The mines that have produced diamonds are the Ozark, Mauney, Arkansas, Kimberlite, and American. Although most of the diamonds at these mines have been found on or near the surface, others have been found at depths of as much as 20 feet.

⁸ Op. cit., pp. 27-28.

How much deeper the diamonds may lie is not known, but they probably extend to depths much greater than that to which mining can be carried.

The yield of diamonds in carats per load of diamond-bearing material differs at different places in the mines and also at different depths. This yield, as it has been determined from the great amount of work at one mine, is 1 carat for 8 loads (16 cubic feet) of diamond-bearing material. In South Africa the yield of diamonds ranges from 6 to 42 carats from 100 loads.

Most of the diamonds from the Ozark, Mauney, and Arkansas mines have been obtained within the areas in which the volcanic breccia is exposed. Austin Q. Millar, one of the operators, states that the soft, decomposed peridotite overlying the "hardebank" (massive intrusive peridotite) in the north part of the Mauney mine is nearly or entirely barren of diamonds, and that the soft blue, somewhat banded earth (altered peridotite tuff) that covers a small area on the Ozark mine is barren of diamonds.

The diamonds have probably been concentrated on and near the surface by weathering and erosion. The great amount of erosion that the peridotite has undergone has removed from the outcrop of the peridotite much of the clay and other minerals having a low specific gravity leaving perhaps most of the diamonds and other heavier minerals. The heavier minerals thus concentrated are in the black ground. Mr. Miser has shown, by panning samples of black ground and of the underlying green and blue grounds, that the quantity of heavier minerals to the cubic foot is many times greater in the black ground than in the underlying material. The supposition that there has been a surficial concentration of diamonds is also apparently supported by the results of washing done by the Ozark Diamond Mines Corporation, which obtained a larger yield of diamonds from surface material than from the underlying disintegrated rock.

The number of diamonds that have been found near Murfreesboro, Ark., since their discovery in 1906 is only known in part, for the mining companies have withheld from publication the figures showing complete production. So far as the authors know, however, the output to date amounts to at least 10,000 diamonds.

Most of the diamonds from the mines near Murfreesboro have been held by the mining companies, though some uncut stones have been sold. The first cut stones were offered for sale in 1921 by Tiffany & Co., of New York City, and by the Chas. S. Stiff Co., of Little Rock, Ark.

The diamonds that have been found range in weight from a very small fraction of a carat to many carats. Some are so small that 250 of them would be required to weigh 1 carat. The largest

diamond, which was found in the Arkansas mine in the summer of 1924, weighed 40.23 carats; one weighing 20.25 carats was found in the Arkansas mine in September, 1921, and one weighing 17.86 carats was found in the same mine in May, 1917. The average weight of the 3,000 diamonds that had been produced by the Arkansas mine at the end of 1920 was about 0.4 carat, but the average weight of the diamonds that make up the entire product of all the mines is probably between 0.3 and 0.4 carat.

Most of the diamonds are white, brown, or yellow. According to Kunz and Washington, there is a large proportion of white stones, most of them of a high grade in color, brilliancy, and freedom from flaws. These authors also say that many of the stones are as fine as any that have been found elsewhere, and that some of the yellow ones are of exceptional quality and color. In describing several yellow, brown, and white stones from the Arkansas mine Kunz says: "These are absolutely perfect and are equal to the finest stones found at the Jagersfontein mine, or that were ever found in India."

Mr. Millar states that the white stones comprise 40 per cent of the mine run yield from the Mauney and Ozark mines, that the yellow stones comprise 22 per cent, the brown stones 37 per cent, and bort 1 per cent. Stones having a blue or pink tinge have been found and occasionally a "frosted" or etched white stone is found. Most of the diamonds are crystals, and the most common forms are trisoctahedrons and hexoctahedrons, though some octahedrons and dodecahedrons are found. Crystals with sharp angular faces are rare; rounded surfaces greatly predominate. Fragments and fractures are much more numerous among stones recovered from surface material than they are in stones taken from slight depths in the volcanic ground.

The diamonds shown on Plate 2, Figure 1, are all crystals and are described by W. T. Schaller as follows:

The crystals seem to be rounded and distorted hexoctahedrons; the bounding faces are not typical crystal faces but are end forms toward which the curved faces tend.

Crystal No. 1: Slightly smoky or brownish in color; probably a flattened and distorted octahedron or hexoctahedron with possibly additional forms. Several of the rounded faces have parallel octahedral-like "etch hills" or "ridges" on them.

Crystals Nos. 2 and 3: Colorless; probably distorted flattened hexoctahedrons.

Crystal No. 4: Brownish; elongated crystal with ends not complete; a different phase of distortion.

Crystal No. 5: Yellow; very little distorted; essentially a rounded octahedron, the octahedral faces being replaced by the rounded faces of a hexoctahedron. Shows several solution "pits," one quite deep, in the position of the cube.

Crystal No. 6: Colorless; suggestion of a flattened octahedral twin but may be only a distorted form like the others.

Crystals Nos. 7 and 8: Yellow; like crystal No. 5.

Crystals Nos. 9 and 10: Colorless; rounded, flattened, and distorted hexoctahedrons.

MINING AND TREATMENT OF DIAMOND-BEARING MATERIAL

Probably several hundred diamonds have been picked up by miners from the surface of the peridotite areas, especially the Prairie Creek area, but most of the diamonds have been obtained by washing the diamond-bearing material. Different methods of mining and washing have been employed, in part because of the diverse character of the diamond-bearing material which differs not only from one locality to another but also at different depths.

Much of the decomposed peridotite, including the surficial black soil called "black ground" and also a large part of the underlying "blue ground," "yellow ground," and "green ground," is soft enough to be washed for the recovery of the diamonds without being crushed or weathered first. Most of the black ground is very sticky, like gumbo, when it is wet, so that it disintegrates with some difficulty in the washing plants. Experiments are said to show that when thoroughly dried and then washed it absorbs water rapidly, swells, and finally slacks to a thin mud. Much of the diamond-bearing material, especially that of some of the "blue ground" and "green ground," is fairly hard and requires crushing, exposure to weathering, or other treatment for the recovery of diamonds. The unaltered peridotite, called "hardebank," and the unaltered peridotite breccia are so hard and tough that they probably can not be treated in any way for the extraction of diamonds except by crushing, which would doubtless fracture some of the diamonds.

All the mining has been done in shallow open cuts. Some hydraulic mining has been done (pl. 3, fig. 1), but most of the material mined has been removed by hand and by means of plows and scrapers, and hauled to washing plants in tram cars which have a capacity of 16 cubic feet each.

In hydraulic mining the water carries the disintegrated diamond-bearing material through a sluice trough, from which the sluiced materials are washed into small plants, where they are sized and jigged. Then the concentrates are placed on smooth sheets of metal and carefully searched for diamonds.

A log washer was used for a short time in the Ozark washing plant, but it was not successful on account of the stickiness of the "black ground" that was washed in it.

Washing pans of the type common in the South African diamond fields have been successfully used. Such a pan is circular, has a

flat bottom, and rests in a horizontal position. At its center there is a vertical revolving shaft to which radiating arms are attached. On these arms are metal teeth that revolve in the pan and thus stir the diamond-bearing material that is fed into the pan. During this stirring the diamonds and associated heavy minerals gradually settle to the bottom of the pan, while the clay and other light minerals rise to the surface and flow out of the pan near its center. The concentrates thus obtained in the bottom of the pan are then sized and next jigged. The jigged concentrates are carefully searched for diamonds on metal-covered tables or are washed by water over a table which is covered with a thick film of grease and which is shaken rapidly from side to side by an eccentric. While the concentrates are washed across the table the grease sticks to the diamonds and holds them, whereas it does not stick to the other minerals, most of which are therefore washed off the table. The grease and the diamonds and other minerals embedded in it are removed from the tables from time to time. The diamonds are then freed from the grease by converting it into soap or by putting it into boiling water.



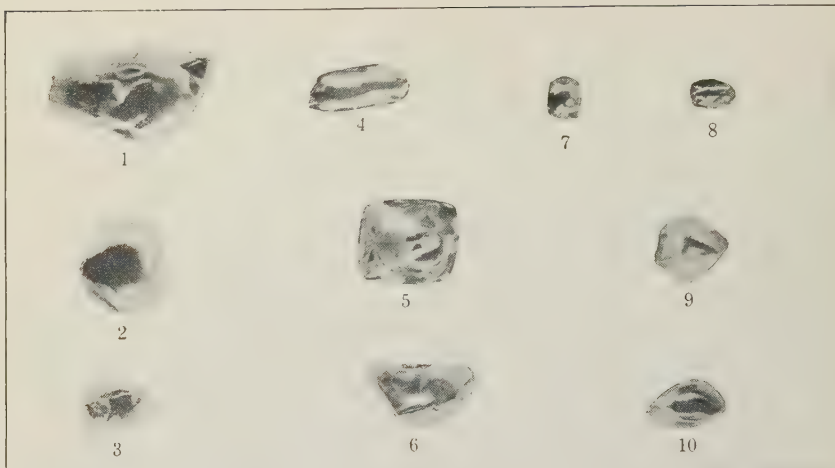
1. THE ARKANSAS DIAMOND MINE, NEAR MURFREESBORO, ARKANSAS

Deeply weathered peridotite underlies all the treeless area and has been mined by means of a drag-line scraper



2. TRENCH IN SOFT DECOMPOSED PERIDOTITE ON THE ARKANSAS MINE

Lee Wagner, the man standing in the picture, has found more North American diamonds than any other man on the continent



**I. DIAMONDS FROM THE ARKANSAS MINE, PIKE COUNTY, ARKANSAS.
NATURAL SIZE**

The diamonds shown in the picture are owned by Col. Washington A. Roebling, Trenton, New Jersey. They are crystals, with the following weights: No. 1, 11.21 carats; No. 2, 6.83 carats; No. 3, 3.30 carats; No. 4, 2.77 carats; No. 5, 17.86 carats; No. 6, 4.40 carats; No. 7, 1.19 carats; No. 8, 0.91 carat; No. 9, 2.50 carats; and No. 10, 1.40 carats. Other information concerning the crystals is given on pages — and —.



**2. ALTERED VOLCANIC BRECCIA ("BLUE GROUND") IN CUT OF OZARK MINE,
NEAR MURFREESBORO, PIKE COUNTY, ARKANSAS**

The bedding dips about 30° W.



1. DIAMONDS ARE BEING MINED AT THE ARKANSAS MINE BY MEANS OF A POWERFUL JET OF WATER AND THEN CARRIED THROUGH A SLUICE TO THE PLANT PICTURED BELOW



2. DIAMOND PLANT AT THE ARKANSAS MINE

Here the sluiced material is sized and jigged. Then the concentrates, after being placed on smooth sheets of metal, are carefully searched for stones

RECENT PROGRESS AND TRENDS IN VERTEBRATE PALEONTOLOGY¹

By W. D. MATTHEW

INTRODUCTION

In science, as in our business and personal affairs, it is profitable from time to time to look over the ground and see how much we have accomplished in recent years. The present occasion would seem to be a suitable one in which to render an account of recent progress in that branch of paleontology with which I am principally acquainted. It is not a catalogue of recent publications, nor a summary of their contents that is presented in this address, but rather a report of progress, with some suggestions as to where this progress seems to be leading us.

The foundations of paleontology, the documents on which our researches are based, consist of the collections of fossils, which are our record of the past history of life. The breadth and solidity of those foundations must determine both the size and the permanence of the structure that we may erect thereon. It is no small part of our duty as architects thereof to examine carefully from time to time into the adequacy of these foundations, to condemn and sweep away such parts of our structure as appear to be insufficiently supported, flimsy, or outworn. They may have served their purpose in the past as temporary outworks, trial sketches or models, or provisional scaffolding to aid in the erection of our more permanent structures; but they should not be confused with solid and stable additions, nor should they be allowed to outlive their usefulness. A critical review of our foundations and of their recent extension is the foremost and most important matter before us.

In the early days of paleontology fossil vertebrates were known from few and mostly very fragmentary specimens. Our concepts of extinct animals were built up from the study and correlation of numerous fragments, supplemented largely by the analogy of living relatives of the extinct animals. The correlations were sometimes incorrect, the analogies were always inexact and often misleading. Of the theories and conclusions based by our predecessors on these relatively scanty foundations, some have been swept away and for-

¹ Presidential address delivered before the Paleontological Society Dec. 29, 1922. Reprinted by permission from the Bulletin of the Geological Society of America, vol. 34, Sept. 30, 1923.

gotten, some have been modified in varying degree, some have been confirmed and vindicated by subsequent discovery.

The more intensive collecting of recent years, and especially the technique devised by Hatcher and Wortman for the purpose of preserving the whole of a fossil skull or skeleton, have brought in year by year a larger proportion of complete specimens of fossil vertebrates. The leading American museums are to-day peculiarly rich in complete and well-preserved material, and the more progressive museums of Europe have likewise adopted these methods, greatly to the improvement of their collections.

It is difficult to find any basis for a quantitative estimate of the increase in our collections, or even of any particular portion of them. So far as the American Museum collections go, the Cope collection, gathered between 1872 and 1896, covers about 25 per cent of the catalogue numbers, but is not in reality over 10 per cent of the collections in this department, as in former years many specimens were separately catalogued that would not now be considered worth individual record. The other 90 per cent was gathered during the last 30 years, and progressively more during the later decades. Perhaps it would be fair to say that 20 per cent was gathered from 1892-1902, 30 per cent from 1902-1912, and 40 per cent from 1912-1922. Other institutions would have proportions different from these. Probably in Yale University or the National Museum the proportion of material collected and prepared over 30 years ago would be higher; on the other hand, in the newer institutions all the material is relatively recent. It is reasonable to regard the American Museum as fairly representative in this matter and to conclude that, so far as American collections go, nine-tenths of them have been obtained during the last 30 years and nearly half during the last 12 years.

Progress in foreign museums has not been so rapid, especially in Europe, where the earlier collections were more important and the World War seriously curtailed, if it did not eliminate, all scientific activities. Yet even in Europe large additions have been made since the beginning of the century and some important ones within the last decade. Judging from what I saw of the principal European museums in 1900 and again two years ago, it would, perhaps, strike a fair average to estimate that their collections have been nearly doubled since 1900.

I will try to specify the more important points in the progress of the last 10 or 12 years.

PALEOZOIC REPTILES, PERMIAN OF TEXAS AND SOUTH AFRICA

On the origin of land vertebrates there is little to report in the way of new discoveries, although the researches of Gregory and Watson in respect to the relations of the earliest land vertebrates to

the fringe-finned fishes have advanced our understanding of the problem; nor have any important new collections been made among the earliest land vertebrate faunas of the Pennsylvanian period. Moodie's monographic revision of the Coal Measures amphibia and reptiles² affords a most valuable compendium of what is known up to the present time.

In the Permian faunas, both in Texas and South Africa, there has been a great advance, both in collecting and research, continuing the activity of the previous decade. Professor Case,³ of Michigan University, and the late Doctor Williston,⁴ at the University of Chicago, have been the leaders in this country, and have secured and described large collections from Texas and Oklahoma and greatly increased our knowledge of this ancient vertebrate fauna. The Cope Permian collections at the American Museum have been studied and compared with the South African faunas by Case, Gregory,⁵ Broom,⁶ Watson,⁷ and von Huene,⁸ and important collections from the Texas Permian have been obtained for the Tübingen and Munich museums in Germany. There shall be noted, also, the fine skeleton of the fin-back reptile *Dimetrodon*, recently mounted in the National Museum.⁹ The South African Permian has also been vigorously exploited by Broom, Watson, Haughton,¹⁰ and Van Hoepen¹¹ and large collections made, including many finely preserved skulls and skeletons. This fauna is of peculiar interest as containing apparently the beginnings of the evolution of mammals, birds, and dinosaurs. It is significant that it is regarded as the fauna of an arid or desert region,

² R. L. Moodie (1916): The Coal Measures amphibia of North America. Carnegie Inst. Pub. No. 238.

³ E. C. Case (1907): Revision of the Pelycosauria. Carnegie Inst. Pub. 55; 1910, articles in Amer. Mus. Bull., vol. xxviii; 1911, Revision of the Cotylosauria, Amphibia, and Pisces of the Permian of North America. Carnegie Inst. Pub., nos. 145, 146; 1913, Permocarboniferous vertebrates from New Mexico. Idem., no. 181; 1915, Permocarboniferous Red Beds of North America, etc. Idem., no. 207; 1919, Environment of vertebrate life in the late Paleozoic of North America. Idem., no. 283.

⁴ S. W. Williston (1911): American Permian vertebrates. Univ. Chicago Press; and various articles, mostly in the Journal of Geology, 1908 to 1918.

⁵ W. K. Gregory: Various articles in Bull. Amer. Mus. Nat. Hist., 1908 to 1922; 1913, Journal of Morphology.

⁶ R. Broom (1908-1922): Numerous articles in Bull. Amer. Mus. Nat. Hist., Proc. Zool. Soc. London, Ann. South African Museum, etc.

⁷ D. M. S. Watson (1912-1922): Numerous articles in Ann. Mag. Nat. Hist., Proc. Zool. Soc. London, Trans. Roy. Soc. London, Geol. Mag., etc.

⁸ F. Von Huene (1922): Osteologie des *Dicynodon* Schädel, Pal. Zeitsch., V, 58-71; 1913, Skull elements of Permian Tetrapoda, Bull. Amer. Mus. Nat. Hist., vol. xxxii. 315-386; 1912-13, Anatomischer Anzeiger, 42 Bd., s. 98, 472; 43 Bd., s. 389, 519.

⁹ C. W. Gilmore (1919): A mounted skeleton of *Dimetrodon gigas*. Proc. U. S. Nat. Mus., vol. 56, pp. 525-539, pls. 70-73.

¹⁰ S. H. Haughton (1915-1918): Ann. S. African Mus., vol. xii, containing descriptions of the paleontological material of the S. African Museum and Geol. Surv. S. Africa; 1919, Review of the reptilian fauna of the Karroo system of South Africa. Trans. Geol. Soc. S. Afr., vol. xxii, pp. 1-26; 1920, On the genus *Ictidopsis*. Ann. Durb. Mus., vol. ii, part v; 1921, On the reptilian genera *Euparkeria* Broom and *Mesosuchus* Watson. Trans. Roy. Soc. S. Afr., vol. x, pp. 81-88.

¹¹ Van Hoepen (1915): Ann. Transvaal Mus., vol. v, nos. 1, 2.

rather in contrast to the fluviatile or littoral facies represented by the Texas Permian.

The third great area for Permian vertebrates, the Dvina River, in Poland, has not, so far as I know, been seriously exploited since the work of Amalitzky, 20 years ago, nor has anything been added to Fritsch's pioneer work in Bohemia.

With all that has been done, we really know very little as yet of the Permian land animals. The period was a most important and critical one in the evolution of land life, for it witnessed the first great expansion of land vertebrates, and the origin, probably, of mammals, birds, and the principal orders of reptiles, including dinosaurs. What we know best is the river-delta fauna of the Lower Permian in Texas, a series of plains or desert faunæ of Upper Permian age in South Africa, and probably a similar facies in Poland; a small Permian swamp fauna in Bohemia, and a few items from other regions. These must represent but a small proportion of the variety and scope of land life of the Permian world. How imperfect a picture it gives may be judged by supposing that our knowledge of the modern land vertebrates were similarly limited to the animals of a South African desert, a Texas delta, and a swamp in central Europe, with a few odds and ends from elsewhere. The zoogeographer would be bold indeed who propounded theories of distribution and migration based on data so limited, and it is to be feared that his conclusions would bear but little relation to the realities. While it is thus necessary to emphasize the limitations of our knowledge, it is but fair to say that it is vastly greater than it was a decade or two ago. The number of genera on record is not so greatly increased, but our systematic and anatomical acquaintance with the characteristic types is more than doubled.

TRIASSIC REPTILES AND AMPHIBIANS OF GERMANY

Turning to the age of reptiles, we have in the Triassic the least known chapter, so far as America is concerned, and very little has been added to this chapter in the last decade. What little has been accomplished in this direction is due to the energetic prospecting of Doctor Case, and contains promising prospect for the future as well as a few but very interesting additions to the Triassic faunæ.¹² In Europe, however, the recent discoveries of Triassic dinosaurs at Halberstadt and Trossingen in Germany and the discovery of a complete skeleton of a South African Triassic dinosaur have given an adequate basis for the study of these primitive dinosaurs and appreciation of their real relations to the specialized dinosaurs of the later geologic periods. Especially is the discovery by von Huene,

¹² E. C. Case (1922) : Carnegie Inst. Pub. no. 321.

in new excavations at Trossingen during the past two seasons, of a series of a dozen or so more or less complete dinosaur skeletons likely to be of great scientific value. Scarcely less important is a large quarry of skulls and skeletons of the great Triassic labyrinthodont *Mastodonsaurus*, in the Black Forest region by Professor Wepfner, and the discovery of complete skeletons of the very peculiar reptile *Placodus*, whose teeth were found long ago in Germany and supposed to be the pavement-teeth of a fish allied to the rays. This fine skeleton is being studied by Doctor Drevermann, of the Senckenberg Museum.

JURASSIC DINOSAURS OF UTAH AND EAST AFRICA

The two outstanding features of progress in Jurassic land reptiles are the great dinosaur quarry worked by the Carnegie Museum near Jensen, in the Vernal Valley, Utah, and the Tendaguru dinosaur collections from German East Africa secured for the Berlin Museum. So far as I can judge from the record maps of the Jensen quarry, which I had the privilege of inspecting through the courtesy of Mr. Douglass, the material secured there is greater in quantity and finer in quality than the sum of all that has been obtained hitherto in America. The preparation of this huge collection will be a labor of many years, however it be arranged; but as a result we may look forward confidently to more than doubling our present knowledge of Morrison dinosaurs.

The memoirs by Gilmore¹³ on the carnivorous and armored dinosaurs in the National Museum, chiefly of the Morrison fauna, are of the highest authority and importance, and his restudy of the Potomac fauna¹⁴ of Lower Cretaceous age shows that it is not the Morrison, as formerly supposed, but of decidedly later age. The Tendaguru collection is likewise an immense task in preparation, and when I saw it in Berlin, 2 years ago, it was far from being completed, after more than 10 years' work. It provides a fairly complete skeletal knowledge of some half dozen types of dinosaurs¹⁵ and fragments of a few others, representing a fauna similar in broad lines to the

¹³ C. W. Gilmore (1920): Osteology of the carnivorous dinosauria in the U. S. Nat. Mus., Bull. 110, U. S. Nat. Mus.; 1914, Osteology of the armored dinosauria in the U. S. Nat. Mus., Bull. 89, U. S. Nat. Mus.; see also 1909, Osteology of *Camptosaurus*; 1915, Osteology of *Theselosaurus*, and other articles in Proc. U. S. Nat. Mus.

¹⁴ C. W. Gilmore (1921): Fauna of the Arundel formation of Maryland. Proc. U. S. Nat. Mus., vol. lxx, pp. 581-594, pls. cx-cxiv.

¹⁵ W. Janensch (1914): Übersicht ueber die Wirbelthierfauna der Tendaguru-Schichten. Archiv. f. Biologie, lxxi, 79-110; also pp. 217-261. Ueber *Elaphrosaurus* u. s. w., Sitzber. Gesell. naturf. Freunde, 1920, pp. 225-235.

W. Branca (1914): Die Riesengröße sauropoder Dinosaurier vom Tendaguru, u. s. w., Archiv. f. Biologie, vol. lxxi, pp. 71-78.

Pompeckj (1920-23): Personal communications.

E. Hennig (1912): Am Tendaguru; also various articles in Sitzber. Gesell. naturf. Freunde, 1912-1922.

Morrison fauna, nearly similar in its adaptive facies, and approximately of the same age, but inhabiting a different continent, and of the highest importance in giving some really adequate data as to the faunal distribution at that epoch. It is too early yet to draw conclusions, but my impression from a superficial review was that the Tendaguru and Morrison faunas showed a very close adaptive similarity, but were not so closely related as they seemed. It is, fortunately, possible to correlate the Tendaguru dinosaurs exactly through marine faunas in interdigitating formations. This in turn aids greatly in the correlation of the Morrison fauna, and Schuchert has shown¹⁶ that there is strong reason to place it rather at the end of the Jurassic than at the beginning of the Cretaceous. This conclusion is further supported by Gilmore's new evidence as to the relations of the Potomac fauna.

CRETACEOUS DINOSAURS OF ALBERTA, MONTANA, AND NEW MEXICO

It is in the Cretaceous dinosaurs that we can record the greatest progress in the last 10 or 15 years. It is not so long ago that our practical knowledge of Cretaceous dinosaurian faunas was almost confined to one horizon and to one small area. Substantially, it was the Lance fauna that we knew, and to what extent the fragmentary fossils recorded from other formations and other areas were really distinguishable from those of the Lance was a subject of acrimonious debate. To-day we have extended the scope of our geographic knowledge as far as central Alberta to the north and New Mexico to the south, and have been able to distinguish four well separated geologic zones, each represented by a fauna known from a series of more or less complete skeletons. The earliest of these faunal zones is the St. Mary's of the Milk River district in Montana; the second and best known is the Belly River of the Red Deer River in Alberta; the third is the Edmonton of the same region, and the fourth, the Lance of Wyoming and Montana. The great collections secured from the Belly River by the American Museum, the Ottawa, Toronto, and Edmonton museums in Canada, and the Field Museum in Chicago are still being prepared and studied, but it is already evident that it was a surprisingly large and varied fauna, of which the Lance was but a remnant, consisting of a few highly specialized survivors.¹⁷

¹⁶ C. Schuchert (1918) : Bull. Geol. Soc. Am., vol. 29, pp. 245-280.

¹⁷ B. Brown (1912-1917) : A series of papers in Bull. Amer. Mus. Nat. Hist.

H. F. Osborn (1917) : Bull. Amer. Mus. Nat. Hist., vol. xxxv, pp. 733-771.

L. Lambe (1914-1920) : Numerous articles in Mem. Geol. Surv. Canada, Ottawa Naturalist, Trans. Roy. Soc. Canada, etc.

W. A. Parks (1919-1922) : Series of articles in Univ. Toronto Studies, Trans. Roy. Soc. Canada, etc.

Another interesting phase of recent progress in this group is the probable difference in faunas widely apart geographically and in different climatic zones. The splendid specimens secured by Charles H. Sternberg in the last two seasons in the San Juan basin of New Mexico appear to represent a fauna clearly distinct from any of the three great northern faunas. Their true correlation has yet to be determined by a more exact study of the fauna and stratigraphy, but Mr. Sternberg's latest work, performed under heavy handicaps opens up an important new field for dinosaur collecting and is the last of a long series of important finds made by him during the last 50 years. A fine skull and much of the skeleton of a gigantic Ceratopsian has been secured by the American Museum; other important specimens are still in his hands and in the Upsala Museum in Sweden.

THE DINOSAURS NOT A NATURAL ORDER

The dinosaurs are now generally recognized as not a natural order of reptiles, but a composite group, including two distinct and rather distantly related orders.¹⁸ Dinosaurs correspond in a way to pachyderms among mammals, once considered a natural order, but now recognized as an assemblage of animals superficially alike, owing to parallel adaptation, but not really related. It is in this sense that the term "dinosaurs" should henceforth be used and not as a natural order of reptiles. The two orders are the Saurischia, including Marsh's two groups of Sauropoda and Theropoda, and the Ornithischia, or Orthopoda, the Predentata of Marsh. The first group includes the gigantic amphibious dinosaurs, the great carnivorous dinosaurs, and their slender, swift-running allies, and the more primitive Triassic dinosaurs. Orthopoda include the iguanodonts and duck-billed dinosaurs, the horned dinosaurs, and the armored dinosaurs. All these are distinguished by a horny beak or bill and a more birdlike arrangement of the pelvic bones, and have a certain degree of affinity to primitive birds, whereas the Saurischian order has a corresponding relation to primitive crocodiles. The fine memoirs by von Huene on various Triassic reptilia,¹⁹ by Gilmore²⁰ on the carnivorous and armored dinosaurs, by Osborn on *Camara-*

¹⁸ F. Von Huene (1909): Skizze zu einer Systematik und Stammesgeschichte der Dinosaurier, Centralbl. f. Min. Geol. u. Pal., J'g., 1909, s. 12-22; 1914. Natürliche System der Saurischia, idem, 1914, s. 154-158; 1914, Ueber die Zweistämmigkeit der Dinosaurier u. s. w., Neues Jahrb., B. B. xxxvii, s. 577-589.

¹⁹ Von Huene (1912-1916): Series of memoirs and shorter articles chiefly in Palaeontographica; 1910-1914, Geol. u. Pal. Abhandl.; 1920-1922, Acta Zoologica; 1909-1922, Neues Jahrbuch and Centralbl. f. Min. Geol. u. Pal., etc.

²⁰ See p. 277, footnote 13.

saurus,²¹ and a series of descriptive papers by Brown, Lambe, Parks, and others are the most important published contributions in this field.

CENOZOIC MAMMALS OF WESTERN AMERICA

In the field of Tertiary mammals progress has been made at many points. The great series of Tertiary faunas in this country has been improved all along the line. Collections from each horizon have been greatly increased; many new or little known species are now represented by complete skulls and skeletons. Careful intensive stratigraphic work in the fossil fields and more exact records of all specimens enable us to define more accurately the limits and succession of faunas and evolution of phyla. A great advance has been made in the Lower Eocene and Paleocene faunas, the former representing, as I see it, the true beginnings of the Tertiary mammalian succession in this country, while the latter, whatever its precise geologic position may prove to be, is essentially the culmination and close of a Cretaceous mammal fauna whose earlier evolutionary stages are wholly unknown to us, either because they inhabited upland areas, where their remains were not preserved, or because they lived in some other region whose Cretaceous land faunas have not yet been discovered.²²

In the Lower Eocene the most remarkable discovery is the *Diatryma*, a gigantic ground bird resembling the *Phororhachos* of the South American Miocene, but not related to it and standing apart in a group by itself.²³

In the Oligocene, Sinclair²⁴ has inaugurated an intensive stratigraphic-faunal study of the typical White River bad-lands that will serve as a foundation for comparison and correlation much more exact and accurate than has been possible hitherto. A remarkable fossil quarry opened by the Denver Museum²⁵ in the Chadron formation of Colorado has yielded already a large series of well preserved skeletons and appears to contain still vast numbers.

In the Lower Miocene the great collections of the Carnegie Museum from the Agate fossil quarry have been described by Holland

²¹ H. F. Osborn and C. C. Mook (1921): *Camarasaurus*, *Amphicoelias* and other Sauropods of Cope. Mem. Amer. Mus. Nat. Hist., n. s., vol. iii, pp. 247-387, pls. ix-lxxxv.

²² W. D. Matthew (1913, 1917): Bull. Amer. Mus. Nat. Hist., vol. xxxii, p. 307; vol. xxxvii, pp. 569, 831; 1914, Bull. Geol. Soc. Amer., vol. 25, p. 381; 1921, Am. Jour. Sci., vol. ii, p. 209.

²³ W. D. Matthew and W. Granger (1917): The skeleton of *Diatryma*. Bull. Amer. Mus. Nat. Hist., vol. xxxvii, pp. 307-326.

²⁴ W. J. Sinclair (1921-1922): Four articles in Proc. Am. Phil. Soc., vols. ix and lxi.

²⁵ J. D. Higgins (1921): Ann. Rep. Colorado Mus. Nat. Hist., p. 16.

and Peterson in three fine memoirs,²⁶ and the excellent series of *Moropus* skeletons obtained by the American Museum from the same quarry provide a complete knowledge of this extraordinary animal. Large collections have also been obtained from the Lower Miocene for the Yale, Amherst, and Field museums.

The later Miocene and Pliocene faunas are represented in the Snake Creek quarries in Sioux County, Nebr., which have been worked chiefly by the American Museum.²⁷ While the two great fossil quarries mentioned above contain complete skulls and skeletons of a limited number of large animals—three or four kinds in each—the Snake Creek quarries contain chiefly fragmentary material of a great variety of animals, no less than 50 genera being on my list at present. They are river-channel pockets and are now known to belong to three distinct faunal zones.

Perhaps the most interesting out of a multitude of new forms from these quarries are the upper tooth of an anthropoid primate, *Hesperopithecus*, the first of this group from the American Tertiary, and the complete skeleton of *Pliohippus*, the earliest one-toed stage in the evolution of the horse. Discovery by Troxell of fine skeletons of *Pliohippus*²⁸ and of a Tertiary type of mastodon in the Pliocene of South Dakota, and by Gidley of a large Pliocene fauna in Arizona, should also be mentioned.

The series of later Tertiary faunas discovered by exploring parties from the University of California, on the Pacific coast and in the Great Basin provinces, are a most important addition, as they are almost wholly new fossil fields.²⁹ The material as yet discovered is largely fragmentary, but a considerable series of faunas has been differentiated.

In the Pleistocene the great outstanding discovery is the La Brea asphalt quarries near Los Angeles, remarkable for the numbers, the variety, and the fine preservation of the specimens. The discovery of this unique series makes it possible to describe the more character-

²⁶ O. A. Peterson (1909): Revision of the Entelodontidae. Mem. Carnegie Mus., vol. iv, pp. 41–158, pls. liv–lxii; 1910, Description of new carnivores from the Miocene of western Nebraska, *ibid.*, pp. 205–278, pls. lxxiv–lxxxv; 1920, The American Diceratheres, *ibid.*, vol. vii, pp. 399–476, pls. lvii–lxvi.

W. J. Holland and O. A. Peterson (1914): Osteology of the Chalicotheroidea. Mem. Carnegie Mus., vol. iii, pp. 189–406, pls. xlviii–lxxvii.

²⁷ W. D. Matthew and H. J. Cook (1909): Bull. Amer. Mus. Nat. Hist., vol. xxvi, pp. 361–415.

W. J. Sinclair (1915): Proc. Am. Phil. Soc., vol. liv, pp. 73–95.

W. D. Matthew (1918): Bull. Amer. Mus. Nat. Hist., vol. xxxviii, pp. 183–229.

H. F. Osborn (1918): Mem. Amer. Mus. Nat. Hist., n. s., vol. ii, p. 28; Amer. Mus. Novitates, no. 37.

²⁸ E. L. Troxell (1916): Am. Jour. Sci., vol. xlii, pp. 335–348.

II. F. Osborn (1918): Equidae of the Oligocene, Miocene, and Pliocene of North America, iconographic type revision. Mem. Amer. Mus. Nat. Hist., n. s., vol. ii, p. 162, pls. xxviii–xxx.

²⁹ J. C. Merriam and others (1910–1922): Univ. Calif. Geol. Publ., numerous contributions.

istic forms from series of dozens, or even hundreds, of complete skulls with proportionate numbers of skeleton bones.³⁰

PRIMATES AND MAN

The most widely interesting field of paleontological research is that which deals with the geologic history and evolution of our own race, and in this field there have been a series of discoveries and researches in recent years of the highest importance.³¹

First among these I may place the discovery of complete skeletons of Neanderthal man; the skeleton of Chapelle-aux-Saints, so admirably described by Marcellin Boule;³² the two skeletons of La Ferrassie, soon to be described fully by the same distinguished authority, and a series of less complete but important finds in Germany and other central European States. These discoveries have given a very clear and definite concept of the Neanderthal race, as a species clearly distinct from our own, characterized by a series of well-defined physical peculiarities, nearer in many particulars to the anthropoid apes, but clearly not a direct ancestor of our own species.

The fragmentary skull and jaw found in 1911 near Piltdown, in Sussex, likewise represents an extinct species of man, as different from the Neanderthal man as from our own race. Although corresponding in its nearer approach to the anthropoid apes, it probably is not directly ancestral.³³

Another remarkable skull, discovered at Broken Hill, in Rhodesia, while not of high antiquity, is regarded as representing a survival of the Neanderthal race in South Africa. The Talgai skull from Queensland, rather doubtfully associated with the Pleistocene fauna of Australia, is considered as representing a proto-Australian type of man.

³⁰ F. S. Daggett (1918): Notes on Pleistocene fossils from Rancho La Brea. Los Angeles Co. Mus. Hist., Sci., and Art; Dept. Nat. Sci., Misc. Publ.

J. C. Merriam and others: Ut supra.

W. D. Matthew (1913): Amer. Mus. Jour., vol. xlii, p. 291; 1916, *ibid.*, vol. xvi, pp. 45, 469.

³¹ The literature on fossil primates and the evolution of man is very voluminous. A number of excellent critical reviews of the subject by Osborn, Gregory, Boule, Keith, Sollas, Giuffreda-Ruggeri, Leche, Arldt, and others cite and discuss the chief contributions. The most important recent contributions on Tertiary primates are the following:

W. K. Gregory (1920): Structure and relationships of *Notharctus*. Mem. Amer. Mus. Nat. Hist., n. s., vol. lli, pp. 49-243, pls. xxiii-lix.

H. G. Stehlin (1912-1916): Säugethiere der Schweiz. Eocäns, 7 Teil. Abh. schweiz. paläont. Ges., vols. xxxviii and xli.

G. E. Pilgrim (1915): New Siwalik primates and their bearing on the question of the evolution of man and the Anthropoidea. Rec. Geol. Surv. India, vol. xlv, pp. 1-74, pls. i-iv.

W. K. Gregory (1916): Studies on the evolution of the primates. Bull. Amer. Mus. Nat. Hist., vol. xxxv, 1921, pp. 239-355; Origin and evolution of the human dentition, Baltimore, Williams and Wilkins.

³² M. Boule (1911-1913): L'Homme Fossile de Chapelle-aux-Saints, Ann. de Paléont., vols. vi-viii; 1921, Les Hommes Fossiles.

³³ A. S. Woodward, G. Elliott Smith, Arthur Keith, G. S. Miller, W. P. Pycraft, and others, on Piltdown skull.

The sum of these discoveries is to impress strongly on the mind the probability that our own species is but one out of several human species which lived and flourished and competed one with another during the Pleistocene period; our own species, perhaps through its higher social adaptability, being at last supreme, and sole survivor at the present day. Yet it appears probable that through crossing and intermixture some of the blood of one or more of these extinct species of man still survives here and there among our own race and may yet be recognizable when the application of Mendelism to systematic osteology and paleontology is more fully understood and applied, and also when our collections of the remains of fossil man are so extensive as to admit of such applications. Whatever may be the prospects of getting anywhere along this line, it is quite clearly demonstrated by these recent discoveries that the problem of the ancestry of our race—of the evolution of man—is in reality a much more complex and difficult one than had been assumed either by the exponents or opponents of evolution. It is not one missing link that we have to find, but many. Each of the discoveries I have cited is a "missing link"; but we can not be satisfied with merely answering the challenge of the ignorant, and each discovery serves as a spur to further search.

A remarkable recent discovery is that of a true anthropoid primate in the Lower Pliocene of this country. While the single upper molar which Osborn has named *Hesperopithecus*³⁴ does not prove the precise affinities of the animal, there is no reasonable doubt in the minds of those who have studied the original specimen that it is one of the higher Anthropeidea. The discovery of such a type was not wholly unexpected, as the writer and Mr. H. C. Cook, in describing the Snake Creek fauna in 1909, pointed out that certain badly preserved teeth might perhaps be anthropoid, and that the character of the associated fauna made such a discovery reasonably possible. Nevertheless it was not considered likely, as the formation had been diligently and repeatedly prospected in subsequent years without success.

FOREIGN RESEARCHES AND DISCOVERIES, MISCELLANEOUS CONTRIBUTIONS

Paleontological research in other parts of the world is much less advanced than in North America and Europe, but, in addition to the few discoveries already mentioned, several other important results of exploration have already been secured. In the West Indies a more or less systematic search for fossil vertebrates has been made by the American Museum, the Museum of Comparative Zoology, and the

³⁴ H. F. Osborn (1922) : Amer. Mus. Novitates, no. 37.

W. K. Gregory and Milo Hellman (1923) : Amer. Mus. Novitates, no. 53.

National Museum,³⁵ and considerable well-preserved material secured from the Pleistocene of Cuba and Porto Rico, with fragmentary data on the Pleistocene fauna of Hispaniola and Jamaica. The especial interest of these insular faunas lies in their source and paleogeographic bearings. South America affords an immense field for exploration, but since the death of Florentino Ameghino there is but little progress to record. The explorations begun by the Field Museum will, it is hoped, initiate a new period of advance in our knowledge of the paleontologic history of this continent.

In Africa considerable reconnaissance work has been done at various points, but beyond the Tendaguru and Karroo discoveries already noted, the only finds which can be noted here are the Cretaceous dinosaurs discovered by Strömer in the Libyan desert.³⁶ These are of quite a remarkable type—Sauropods and a peculiar carnivorous genus—the fauna possibly having descended from the Wealden fauna; but careful comparative study is still needed.

In India Doctor Matley has obtained an interesting Cretaceous dinosaur fauna from the Deccan, but only preliminary notices of it have as yet been published.³⁷ The chief advance in Indian paleontology is the admirable stratigraphic and faunal work of Pilgrim in sorting out and correlating the heterogeneous group of faunas hitherto known as the Siwalik fauna.³⁸ The splendid collections of these faunas recently secured by Barnum Brown for the American Museum deserve special mention, as also the discovery of Oligocene and Eocene faunas in Baluchistan and Burma by Cooper, Pilgrim, and Cotter. The gigantic "*Baluchitherium*," of which parts of the skeleton were discovered by Cooper,³⁹ is perhaps the largest known land mammal. Borissiak has reported what seems to be the same animal in Russia, under the name of *Indricotherium*,⁴⁰ and last summer the American Museum secured a complete skull, nearly five feet in length, in Mongolia.⁴¹

The results of the American Museum explorations in Mongolia are probably the most important discovery of the last decade. Central

³⁵ W. D. Matthew (1919): Proc. Amer. Phil. Soc., vol. xviii, pp. 161-181.

H. E. Anthony (1918): Mem. Amer. Mus. Nat. Hist., n. s., vol. ii, pp. 331-435, pls. 1v-lxxiv.

G. S. Miller (1916): Smithsonian Misc. Coll., vol. 66, no. 12; 1922, idem, vol. 74, no. 3.

³⁶ E. Strömer (1914, 1917): Wirbelthier-Reste der Baharije-Stufe. Abh. Kgl. Bay. Akad. Wiss., xxvii, 3^e Abh.; xxviii, 3^e u. 8^e Abh.

³⁷ C. A. Matley (1922): Personal communications. B. Brown (1920-1923.) Ab. lit.

³⁸ G. E. Pilgrim (1912): Vert. Fauna of the Gaj Series. Mem. Geol. Surv. India, vol. iv, no. 2, pp. 1-84, pls. i-xxx; 1913, Correlation of the Siwaliks with Mammal Horizons of Europe. Rec. Geol. Survey. India, vol. xliii, pp. 264-326, pls. xxvi-xxviii.

³⁹ C. Forster Cooper (1911): *Paraceratherium bugtiense*, a new genus of Rhinocerotidae. Amer. Mag. Nat. Hist., vol. viii, pp. 711-716, pl. x; 1913, *Thaumastotherium* [corr. to *Baluchitherium*] *osborni*, a new genus of Perissodactyles. Ibid., vol. xii, pp. 376-381.

⁴⁰ A. Borissiak (1915): Rhinoceros de la Taille d'un Mammoth. (*Indricotherium*, new genus.) Geological Messenger, vol. 1, pp. 131-134 (Russian text only).

⁴¹ H. F. Osborn (1923): Amer. Mus. Novitates, no. —. (In press.)

Asia has hitherto been a terra incognita to the vertebrate paleontologist, and the finding of rich and extensive fossil fields in the Gobi Desert with Cretaceous, Eocene, Oligocene, and Pliocene formations, each yielding considerable faunas and finely preserved specimens, in the first season's exploration, promises to open up a completely new field in vertebrate paleontology.⁴² Other fossiliferous horizons will probably be discovered by further explorations, and the history of the land vertebrates of the great central Asiatic continent in the Mesozoic and Cenozoic eras will be placed on record in considerable detail.

In the cellars and storage racks of many museums, both in this country and abroad, are important collections of fossil vertebrates acquired many years ago, but never prepared or described. The labor and expense of preparing, studying, and describing this material to make it of use to science is as valuable a contribution as though it were fresh from the field. A considerable part of the work in the National Museum and some in the American Museum has dealt with specimens collected long ago for Marsh and Cope. Recently the Yale Museum has made a vigorous and highly successful campaign to prepare and describe the great fossil collections left to that institution by Professor Marsh. A series of articles by Lull, Troxell, and Thorpe in the American Journal of Science testifies to the importance of these additions to our knowledge.

Two very valuable and authoritative memoirs by Doctor Teilhard de Chardin should be noted in this connection. In one the classic Cernaysian fauna at the base of the French Eocene is admirably described and illustrated from the collections in the Paris Museum.⁴³ The relations of this fauna and correlation with the Paleocene faunas of this country are now at last based on adequate data. Of scarcely less importance is Père Teilhard's memoir on the carnivora of the Phosphorite fauna, also based on the unrivaled collections in the museum at Paris.⁴⁴

A third important memoir from the Paris Museum, sumptuously illustrated and admirably presented by the director, Marcellin Boule,⁴⁵ describes the fine collections from the Pleistocene of the Tarija Valley in Bolivia, in the Paris Museum.

Finally, I must not omit to mention a series of great synthetic studies by Osborn, dealing with the later Tertiary Equidæ, now pub-

⁴² W. Granger and C. P. Berkey (1922): Amer. Mus. Novitates, no. 42; 1923, *ibid.*, no. 77.

⁴³ P. de Chardin Teilhard (1921): Mammifères de l'Eocene inférieur français. *Annales de Paléont.*, x, pp. 171-176; xi, pp. 1-108, pls. i-viii.

⁴⁴ Teilhard (1915): Les Carnassiers des phosphorites de Quercy. *Annales de Paléont.*, ix, pp. 100-195, pls. xii-xx; 1920, Sur quelques primates des phosphorites de Quercy. *Idem.*, x, pp. 2-20.

⁴⁵ M. Boule and A. Thevenin (1920): Mammifères Fossiles de Tarija, Mission Scientifique Crequi-Montfort. Soudier, Paris.

lished;⁴⁶ the evolution of the Titanotheres, completed but not yet published, and the evolution of the Proboscidea, still in progress; the practical completion of the splendid monographs on the Santa Cruz Miocene faunas by Scott;⁴⁷ Winge's monograph on the Brazilian Edentata;⁴⁸ and a remarkable series of brilliant textbooks by Othenio Abel, of Vienna.⁴⁹ There are several other excellent textbooks that deserve particular notice, but time will not allow even a mention of them here.

CONCLUSIONS AS TO PROGRESS OF RECENT YEARS

In the foregoing outline of progress I have been concerned chiefly with discoveries of new material, of new records, because it is the scanty and fragmentary nature of the evidence that is the chief limit to research in vertebrate paleontology and the chief source of error in our conclusions. In the phrase of a French reviewer, vast floods of ink have been spilled on problems of correlation, of phylogeny, of paleogeography, where a few questionable fragments of fossil vertebrates formed the salient points of evidence. When in some instances an adequate fauna was discovered, the problem was promptly and conclusively settled, the flood of ink suddenly ceased to flow, and deep calm settled over the controversy.

The fundamental progress achieved appears, therefore, to be measurable better in terms of collections than of researches. I do not altogether agree with a distinguished Columbia professor who declared not long ago that paleontologists had no business to reason on or draw conclusions from their specimens, but should content themselves with describing and illustrating them.⁵⁰ Nevertheless, I do think we should distinguish far more sharply between provisional and tentative conclusions based on scanty and fragmentary data and those which are really proven by adequate evidence.

So far as the older and better known fields of vertebrate paleontology are concerned, the progress of the past few years has been in the way of consolidating and confirming what had been tentatively sketched out by earlier workers. In the newer fields we are reaching

⁴⁶ H. F. Osborn (1918): *Equidæ of the Oligocene, Miocene, and Pliocene*. Amer. Mus. Mem., n. s., vol. II, pp. 1-217, pls. i-lviii.

⁴⁷ W. B. Scott and W. J. Sinclair (1903-1912): *Rep. Princ. Exped. Patagonia*, vols. IV-vi.

⁴⁸ A. H. Winge (1915): *Jerdfundne og nulevende Gumlere fra Lagoa Santa*. E. Museu Lundil, Kjöbenhavn, 1915.

⁴⁹ O. Abel (1909): *Bau und Geschichte der Erde; Das Zeitalter der Reptilien Herrschaft*, Vienna: 1912, *Grundzüge der Paläobiologie der Wirbelthiere*, Schweitzerbart. Stuttgart; 1914, *Die Vorzeitlichen Säugethiere*, Fischer, Jena; 1919, *Die Stämme der Wirbelthiere*, Ver. wiss. Verleger, Berlin-Leipzig; 1920, *Lehrbuch der Paläozoologie*, Fischer, Jena; *Methoden der paläobiol. Forschung* Urb. u. Schwarzenberg, Berlin-Wien; 1922, *Lebensbilder aus der Tierwelt der Vorzeit*, Fischer, Jena.

⁵⁰ T. H. Morgan (1916): *A critique of the theory of evolution*, pp. 24-27.

out and securing the first fruits of exploration—the evidence which will confirm or disprove hypotheses and guesses that hitherto have had free rein.

SOME TRENDS OF MODERN WORK

In the field of paleogeography I may call attention to three publications treating the subject from diverse or opposite viewpoints:

Matthew: *Climate and evolution*, an essay of some 318 pages.

Arlt: *Paleogeographie*, a treatise of 2 ponderous tomes.

Case: *Paleogeography of the Permian*, a quarto volume of moderate dimensions.

It is commonly said that paleogeographic problems should be decided only after marshaling all the evidence in every branch of zoology, past and present, as well as of geology and physiography, that can be brought to bear on it. This is what Doctor Arlt has endeavored to do in his great treatise. I do not hold that view, for it appears to me that unless evidence is thoroughly understood and critically sifted as to its weight and its real significance, it is of no value; and it is obviously impossible for human intelligence to attain a thoroughly critical grasp of so vast a field. On the other hand, the evidence in any one branch, if interpreted rightly, will lead to correct conclusions, and if the conclusions drawn in one field conflict with those drawn in another, it can only be because one or the other is wrongly interpreted. It is not a question of balancing the evidence. If it does not *all* point one way, then there is some mistake in the interpretations placed on the facts. The problem then lies in finding out what is the fallacy and in which field it lies, and whether the evidence in several fields has been vitiated by the same fallacy. It is only thus that one can arrive at true conclusions in problems of this sort. To attempt to decide them by the balance of evidence, as one would settle a problem in taxonomy, is more likely to put one wrong than right.

Doctor Case's volume is of interest as placing a novel and much broader significance on the term paleogeography, making it almost equivalent to what might be called paleoecology. He has little to say in this volume as to the question of continental outlines, so commonly discussed as though it were the whole of the subject, but is concerned chiefly with the habitat of the animals, its nature and changes, and the physical geography of Permian North America.

There has been for the past two decades a tendency among vertebratists to keep more closely in touch with stratigraphic geology. The comparative anatomist, especially in setting forth the evolution and specialization of structures, tends to arrange his material in categories and sequences that show the evolution of structures and organs, but are of course structural and not genetic sequences, as the

animals are all contemporaneous. The paleontologist, however, is dealing with true genetic sequences, exact or approximate; with the evolution of species and genera of animals, not merely with illustrations of how certain structures may have evolved. The time relations of his specimens must be known exactly and carefully considered. This has been always to the forefront in invertebrate paleontology. Much of the early research in vertebrate paleontology, however, was by men who were comparative anatomists rather than geologists, and the fragmentary material with which they had to deal made a thorough practical acquaintance with comparative osteology the first essential to its correct identification and study. It is no less important to-day on account of the complex structure of the vertebrate skeleton; but an inevitable consequence is a certain tendency to take the anatomist's viewpoint and study too much the evolution of structures and not enough the actual sequence in time of the animals themselves. The corrective of this tendency is a closer union with the geologists, and in the founding of our society it was hoped and expected that this would result. So far as I can see, the course of American paleontology in the past two decades has demonstrated the wisdom of this action. The exact records of specimens and more careful stratigraphic studies have enabled us to define horizons and differentiate faunas in much more precise and correct detail; and, with the far larger collections and more complete specimens, the records are adequate to trace in many cases the evolution of species and not merely of structures. The earlier writers on evolution did not attempt this. Gaudry and Hæckel, Rüttimeyer and Kowalewsky, Huxley, and Cope demonstrated from the paleontologic record the evolution of structure. Depéret and Schlosser, Osborn and Scott, and many others have perceived and pointed out this weakness in our evidence and have attempted to trace the true phyla. But it is only recently that the evidence has been adequate to place such attempts on a really sound and permanent basis, and indeed most of our work in this line is still tentative and provisional. Nevertheless, we may expect to see these beginnings extended year by year, and the old structural phylogenies elaborated by the previous generation, and scoffed at with some justice by critics as a vast "schwindelbau," replaced by the veritable records of the phyletic history of races of animals. In so far as this is accomplished, Professor Morgan's strictures on paleontological evolution,⁵¹ which are aimed really at the old methods, not at our modern standards, will be no longer justified. Paleontologists, with the facts before them as to what actually did take place in the evolution of a race of animals, may claim the right to reason and draw conclusions from these data as to the methods and causes of the transmutation of species.

⁵¹ See footnote 50.

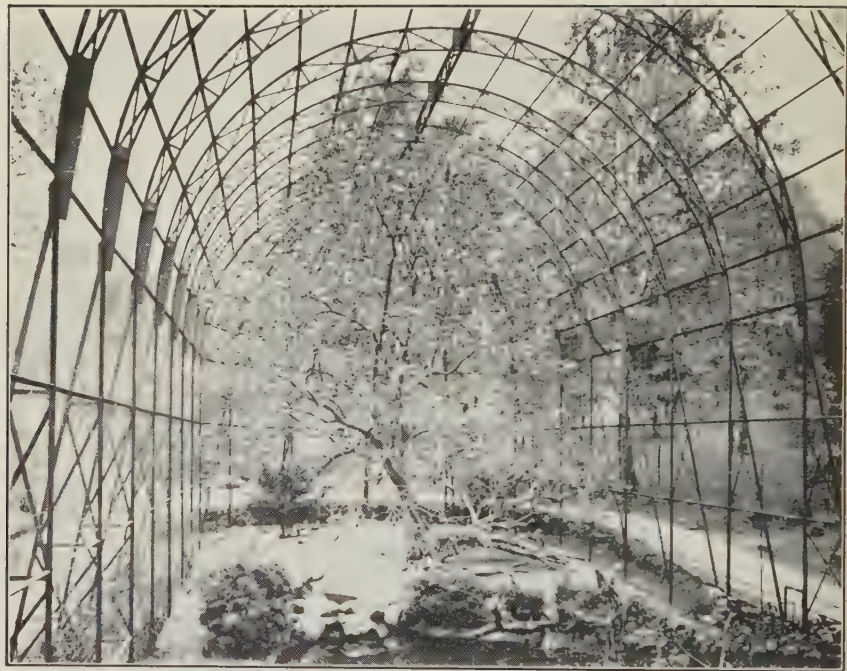
On the anatomical side of paleontology, the far greater completeness of our material in recent years has stimulated comparative researches of high quality, apparent in many of the memoirs I have cited and in a series of memoirs by Gregory, Watson, Broom, Williston, Case, and many others.

Taxonomic researches and revisions have by no means been neglected, but I can mention only one of the many completed or in progress, the revision by Miller and Gidley of the supergeneric groups of rodents, in which, for the first time, the fossil representatives of this order have received adequate treatment in a comprehensive revision.

In looking over the apparent trend of recent advances I am impressed with the honest and conscientious endeavor everywhere apparent to provide a broader and more secure foundation of evidence for our researches by much more extensive collections, more complete specimens, and more exact records. We have tried to get into closer touch with stratigraphic geology on one side, with comparative anatomy and zoology on the other. We have, on the whole, I think, kept fairly clear, considering the great increase in our collections, of the temptation to multiply species correspondingly, the besetting sin of the systematist; and, although the Mendelian school of zoologists will have naught to do with us, we have succeeded, I think, in making very good use of the data and viewpoints that they have emphasized and incorporating them satisfactorily into our own scheme of things.



CHIMPANZEE



GREAT FLIGHT CAGE FOR BIRDS



DAM BUILT BY BEAVERS IN THE NATIONAL ZOOLOGICAL PARK

ANIMALS IN THE NATIONAL ZOOLOGICAL PARK

By N. HOLLISTER

[With 29 plates]

The National Zoological Park, in the city of Washington, was established by an act of Congress approved April 30, 1890, "for the advancement of science and the instruction and recreation of the people," and was placed under the direction of the Smithsonian Institution. Some changes have been made in the original boundary line, and the area now included within the park comprises 175 acres. The park is located in Rock Creek Valley, a district admirably and peculiarly suited for the purposes for which it was selected.

At the time of its establishment the park was some distance from the city proper, but now it is well within the residential district of northwest Washington, almost surrounded by dwellings, and is easily accessible from the heart of the city. No more beautiful site for a zoological park could be desired, and within the fences of this picturesque tract may be found conditions suitable for many of the forms of animal life. The borders of the valley are heavily wooded, and the vegetation in summer almost entirely shuts off the view of the surrounding country. The more open hills and rolling slopes of the interior, where most of the exhibition buildings are placed, are covered with firm sod and excellent lawns, and winding through the length of the valley is picturesque Rock Creek, an affluent of the Potomac River. Systems of automobile roads and bridle paths are maintained throughout the park and walks traverse its most frequented parts.

A collection of about 1,750 living animals is, of course, the feature of the park. There are numerous paddocks and ranges for buffalo, deer, and other large mammals; lakes and pools for waterfowl, seals, beavers, and other aquatic species; outdoor cages, some of large size, for hardy birds and mammals; and houses and shelters for species requiring special care or heated quarters during the winter months. The lion house, near the center of the collection, is at the summit of what is generally known as "lion house hill." In this building are most of the larger cats, the hyenas, the hippopotamuses, and some

tropical mammals. Here also are most of the reptiles. Near by are the monkey house and the bird house, and to the north the antelope house, elephant house, and zebra house. Outdoor yards and cages are placed throughout the park in situations favorable to the comfort and health of the various species exhibited.

The interest of the public in the National Zoological Park is attested by the number of visitors. Over two millions of people now visit the park annually. In 1923 the attendance was 2,393,428, a daily average of 6,558. A large share of the enormous number of tourists to Washington visit the zoo and the sight-seeing cars now regularly include the park in their itineraries. Many people are attracted to the park on account of its walks and drives, and as the entire area is a carefully protected sanctuary for wild birds and flowers, many nature classes from the schools visit it on their field excursions.

Three great classes of animals—mammals, birds, and reptiles—are represented in the collections maintained in the National Zoological Park.

MAMMALS

The mammals (class Mammalia) comprise those creatures commonly known as "animals." They are usually distinguishable from other vertebrates by numerous well-known superficial characters and are briefly defined technically as warm-blooded vertebrates with hair, and with glands in the female for the secretion of milk for the nourishment of the young. Mammals offer a great range of variety in size, general appearance, and mode of life. The elephant, whale, mouse, shrew, and bat present examples showing extremes in bulk and habit. The vast majority of the mammals usually exhibited in zoological gardens belong to the subdivisions of the class known as the ungulates (hoofed mammals), primates (apes, monkeys, and lemurs), rodents (gnawing mammals), carnivores (flesh eaters), and marsupials (pouched mammals). In the National Zoological Park good collections of numerous species of these groups of mammals may be seen and studied to advantage.

THE UNGULATES, OR HOOFED MAMMALS

Modern systematic mammalogists divide the existing "hoofed animals" into four orders—the Proboscidea (elephants), Hyracoidea (hyraxes), Perissodactyla (horses, tapirs, and rhinoceroses), and the Artiodactyla (cattle, sheep, antelopes, deer, camels, swine, and hippopotamuses). The Perissodactyla are called the "odd-toed" ungulates, and usually have an uneven number of toes; as the existing horse with one functional toe, and the rhinoceros with three. The

main axis of the foot passes through the third digit. The tapirs, although having four toes on the forelimb, have only three behind. The Artiodactyla are known as "even-toed" ungulates and have either two or four toes on each foot. These include the true "cloven-hoofed" animals.

The ungulates are important and popular mammals in zoological parks and are peculiarly suitable for exhibition purposes because many species can be shown in open yards or paddocks which approximate in many instances the natural surroundings inhabited by the animals. No less than 50 species are usually shown in the National Zoological Park, many of which are represented by small breeding herds.

THE ELEPHANTS

There are many points of difference between the Indian elephant (*Elephas maximus*) and the African elephant (*Loxodonta africana*), but the most conspicuous mark to separate them is the considerable diversity in the size and shape of the ear, that of the African elephant being much larger than the ear of the Asiatic species. Both kinds are divisible into a number of forms, no less than 11 subspecies of the African elephant having been recognized by one authority. African elephants attain a greater bulk than their Asiatic kindred, but are not commonly seen in shows or parks, almost all the elephants exhibited in circuses being of the Indian species.

Closely allied to the elephant of British India is the elephant of Sumatra (*Elephas sumatranus*). Two young animals of this species were purchased in 1919 by a number of the friends of the children of Washington and donated to the Smithsonian Institution for deposit in the park. At the time of their arrival they were 2 and $2\frac{1}{2}$ years old and were 42 and 45 inches high. They are growing rapidly and are already great favorites with the children, to whom they are known by their Malayan names of "Hitam" (black) and "Kechil" (small).

The African elephant now on exhibition in the park was brought from the Government Zoological Garden at Giza, Egypt, by head keeper Blackburne in 1913. At the time of her arrival she weighed 875 pounds and measured only 4 feet 3 inches in height at the shoulder. In 1923 the same measurement was 7 feet 6 inches. She is known as "Jumbina." She was captured in the region of the Blue Nile and is of the geographical race known as the Abyssinian elephant (*Loxodonta africana oxyotis*). In "Jumbina's" house will be seen a picture of the famous African elephant "Jumbo," probably the largest elephant ever shown in captivity, and a representative of this same Abyssinian race. Near the picture is a

marked pole which shows graphically the great height of that enormous elephant—nearly 11 feet at the shoulder. There are, however, authentic records of wild African elephants of greater size than Jumbo; the highest reliable record is of one which measured 11 feet 6½ inches.

The tusks of elephants are the incisor teeth and are the chief source of commercial ivory. Some of the extinct elephants, as the mastodon, had tusks in the lower as well as the upper jaws. A single tusk of an East African bull elephant has been known to weigh 235 pounds, but this, of course, is far in excess of the normal weight even for a large animal. Heller says the average tusk weight to-day for old wild bull elephants is not more than 40 pounds for each tusk; but before the biggest males were shot off by the professional ivory hunters the average was probably about 80 pounds. Tusks of female elephants are much smaller and more slender than those of males, but sometimes grow to a great length.

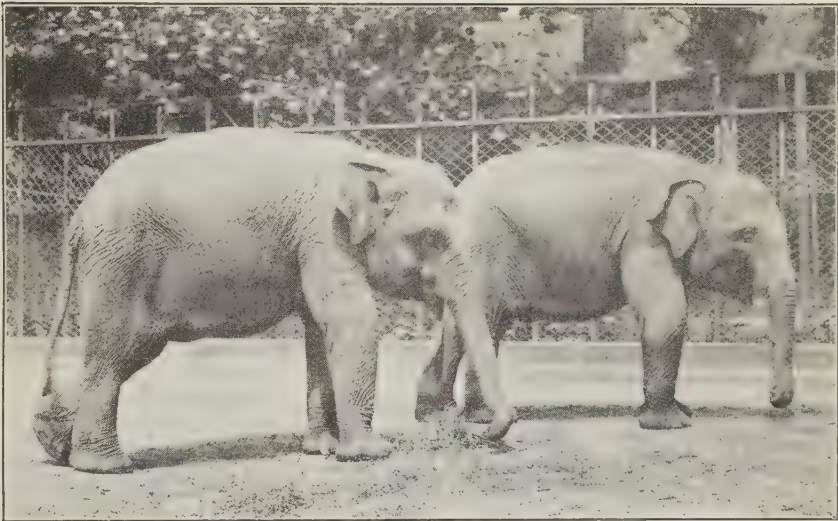
THE TAPIRS

The Brazilian tapir (*Tapirus terrestris*) has been most successfully kept in the Zoological Park and no less than nine young have been reared from a single pair that lived here for many years. Strange to say, this tapir lives equally as well in outdoor yards with warm but unheated quarters as in heated buildings. One fine specimen has withstood the winter weather of Washington since 1911, appears quite unmindful of the cold, and is in perfect condition. It is not at all unusual in winter to see him out enjoying himself in the snow when other animals, even those from temperate or colder climates, have retired to their shelters.

The Malay, or saddle-backed tapir (*Tapirus indicus*) is a strikingly marked species native to the Malay Peninsula, Java, and Sumatra. The back and sides are whitish, sharply set off from the otherwise blackish body. This apparently conspicuous marking is said to have great protective value, since the animal inhabits gray-boulder-strewn wooded regions where the tiger is often its most persistent foe. When lying quietly it is easily overlooked among the boulders.

Young tapirs are pretty little creatures with stripes and spots of yellowish white which gradually disappear during the first eight months after birth.

Other species of tapir are found in the forests of western South America and in Central America north to southern Mexico. The Brazilian species is especially fond of water and spends much of its time in marshy places.



YOUNG SUMATRAN ELEPHANTS



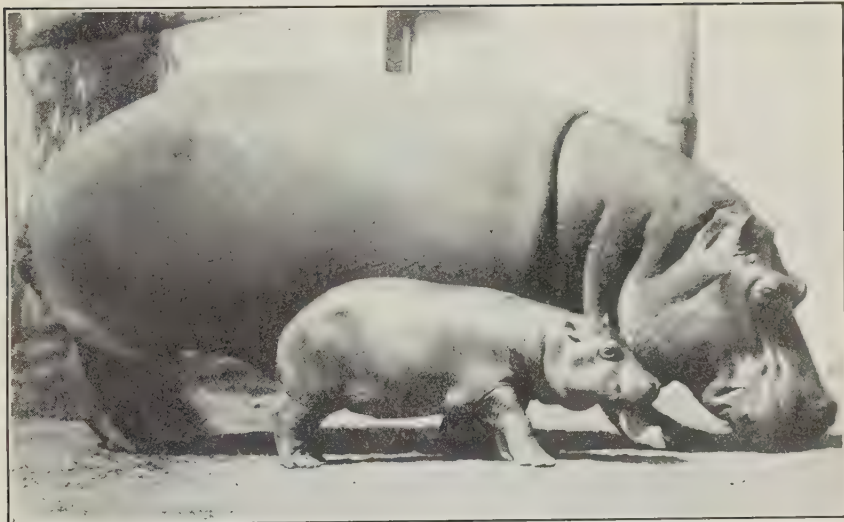
AFRICAN ELEPHANT



MALAY TAPIR



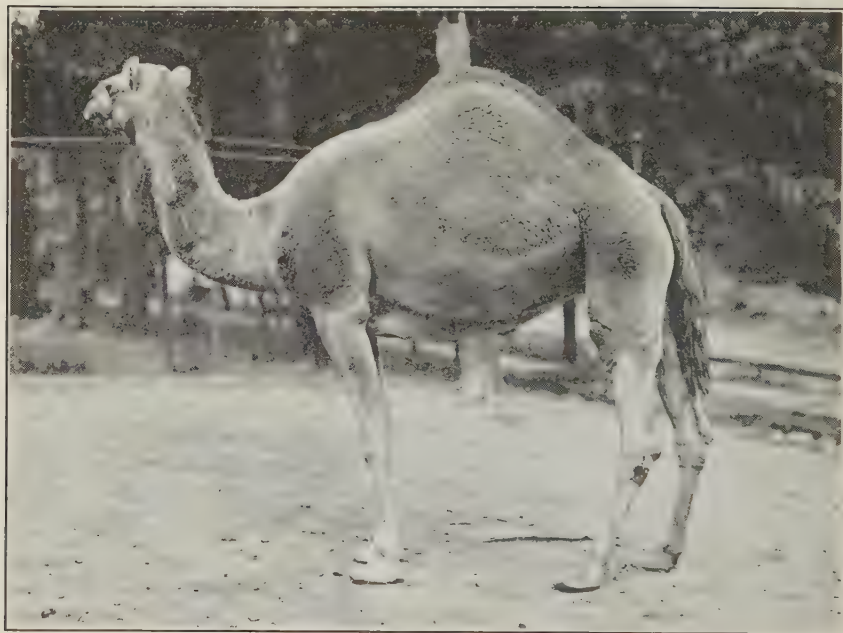
GRANT'S ZEBRA



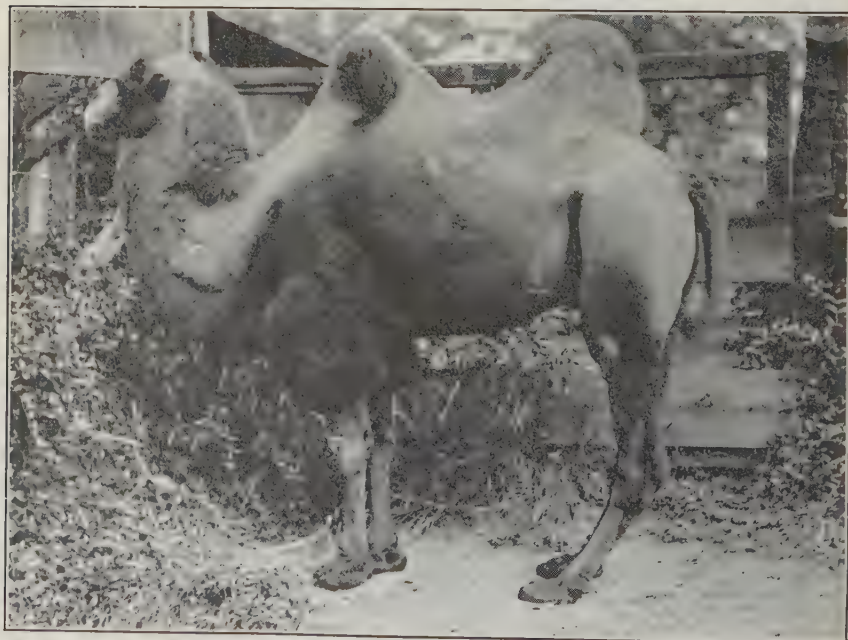
HIPPOPOTAMUS AND YOUNG



COLLARED PECCARY



ARABIAN CAMEL



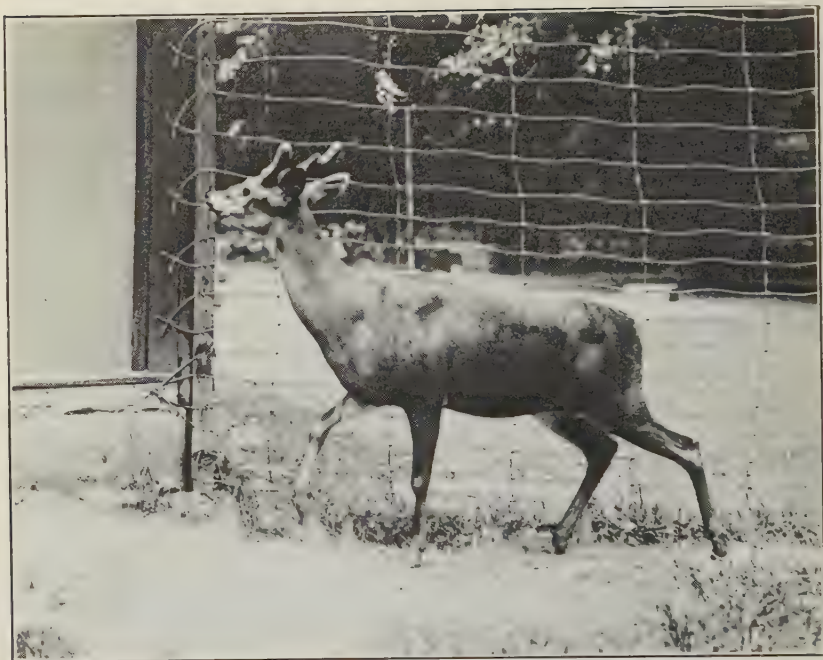
BACTRIAN CAMEL



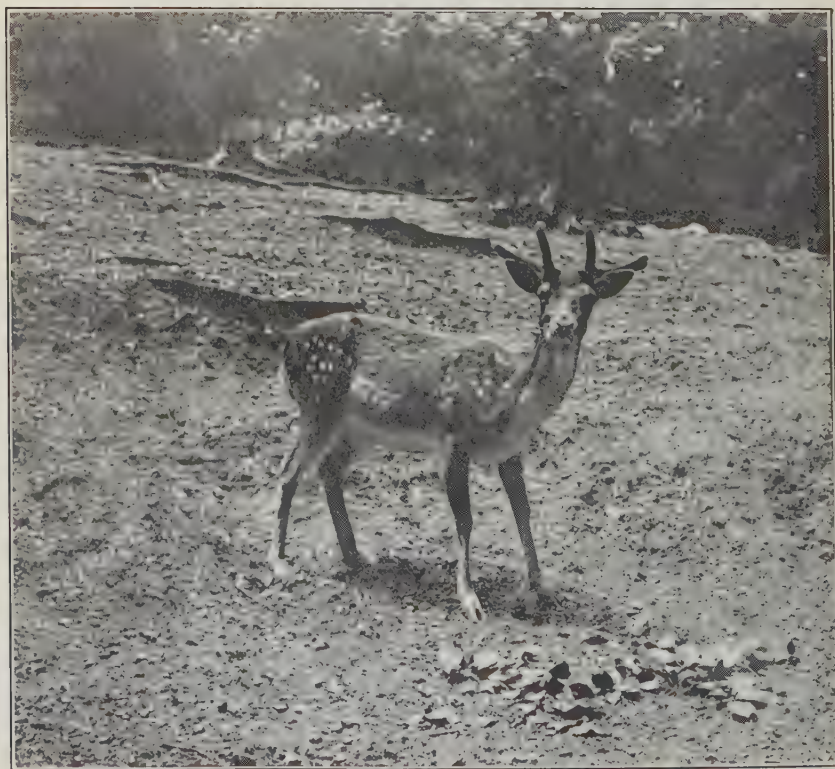
RED DEER WITH ANTLERS IN VELVET



AMERICAN ELK



PANAMA DEER



FALLOW DEER



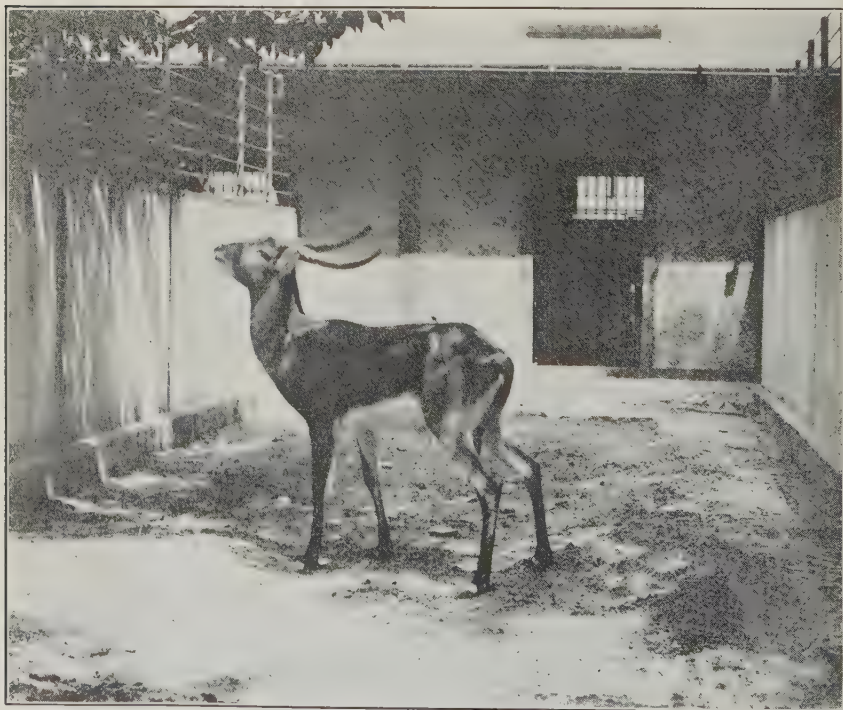
BLESBOK



ELAND



ROCKY MOUNTAIN SHEEP



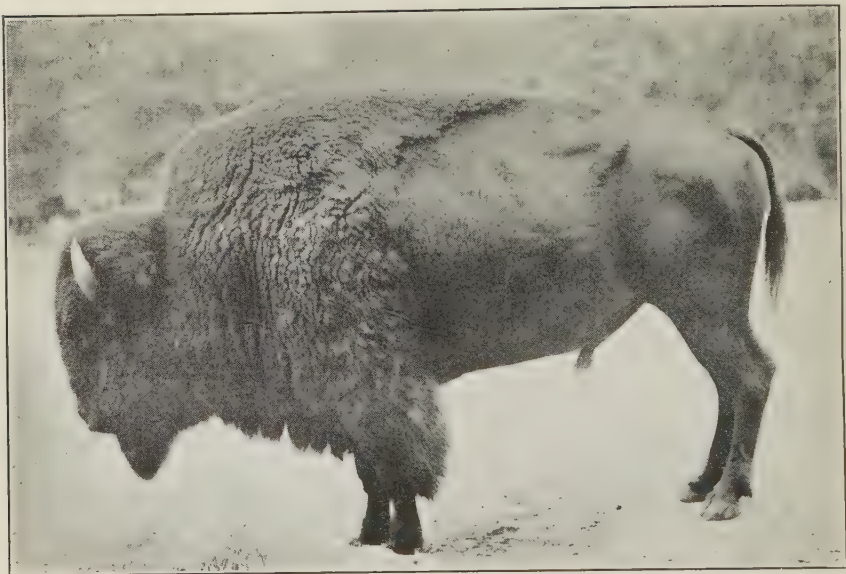
LECHWE ANTELOPE



ARIZONA MOUNTAIN SHEEP



ROCKY MOUNTAIN GOATS



AMERICAN BISON



INDIAN WATER BUFFALO

THE HORSE AND HIS KINDRED

The Przewalski's horse (*Equus przewalskii*) is the only living species of truly wild horse. It inhabits the Gobi Desert region of central Asia where living specimens were captured by an expedition organized by Hagenbeck in 1900. The descendants of this stock are now exhibited in zoological gardens in many parts of the world. In his long shaggy winter coat this horse is a creature of striking appearance. On the outlying borders of the Gobi many of the horses owned by the Kirghiz tribes are apparently mixed with the blood of wild stock.

The specimen of the common East African zebra (*Equus quagga granti*) was brought from Nairobi, British East Africa, in 1909 by Mr. A. B. Baker. He was then a young animal about 18 months old. Zebras are found over much of southern and eastern Africa and in certain localities are very abundant, living in great herds and mingling freely with various species of antelopes and other game. They are much preyed upon by the lion and are a favorite food of the natives.

Grevy's zebra (*Equus grevyi*), a considerably larger and more closely striped species than the common zebra, is confined to the more arid parts of northeastern Africa, especially Abyssinia, Somaliland, and northern British East Africa. It has a much longer and narrower head than the common zebra and is a more handsome animal. The male in the park weighs 880 pounds. The first specimen to reach the park was presented to President Roosevelt by Emperor Menelik of Abyssinia in 1904.

THE RHINOCEROS

Of the five existing species of rhinoceros, three are confined to southern Asia, including some of the larger islands, and two to Africa. The black rhinoceros (*Diceros bicornis*), which is the species on exhibition in the park, is found in Ethiopian Africa. The young example shown came from Rhodesia in 1923, and was then about 1 year old. The horns of rhinoceroses are not comparable to the horns of deer, sheep, and other ruminants, but are outgrowths of the skin and are not definitely connected with the bones of the skull. Rhinoceroses grow to great size; a specimen of the black species shot in Africa by Roosevelt measured 12 feet 3 inches in length of head and body, with the tail 30 inches long. The white rhinoceros of Africa and one of the Indian species are known to exceed these measurements.

THE HIPPOPOTAMUS

Remains of fossil hippopotamuses are found in various parts of Asia and Europe, even in England, but the existing species are

confined to Africa. In addition to the several geographic races of the common species (*Hippopotamus amphibius*), a smaller kind, the pigmy hippo, is known. This latter is confined to western Africa and is very rare in collections. Hippos are essentially aquatic animals and swim with ease. It is said that they remain beneath the surface of the water for so long a time as 10 minutes. On several occasions the introduction of the hippopotamus into the rivers and lakes of the southern United States has been advocated with the expectation that the animal would successfully rid the waters of the congested aquatic vegetation. In view of the serious depredations upon planters' crops which might well be expected, the advisability of such an experiment is questionable.

Of the hippos living in the park, the female and older animal was obtained from British East Africa in 1911. She was then about 2 years old and weighed 800 pounds. She has grown greatly since her arrival and now weighs about 5,000 pounds. She is gentle and loves attention from her keepers. The male hippo came from German East Africa in 1914 and is a much less perfectly tempered animal. He is active and remarkably agile for a beast of his great bulk and can turn and charge with great speed. Three young have been successfully reared from this pair. At birth they weigh about 45 pounds and are expert swimmers. The hippos are quartered in the lion house, where they have access in summer to large outdoor yards and a tank. In winter they are furnished with heated water for their bath and frequently cause great commotion by their vigorous splashing.

THE WILD SWINE

The wild boar of Europe (*Sus scrofa*) typifies the family of swine. It is presumably the ancestral form of the domestic races. A fine example is shown in a yard near the elephant house. The wart hog of Africa (*Phacochoerus aethiopicus*) is famous for his ugly appearance and huge tusks.

The American representatives of the pig family, the peccaries, are found wild from Texas southward over much of Middle and South America. Two general types are distinguished, the white-lipped and the collared peccaries. The latter ranges farther to the north than the larger white-lipped group and was formerly common in the United States along the Mexican border. Although peccaries are doubtless at times, especially when roving in large packs, dangerous beasts to encounter, the stories told of their ferocity are often greatly exaggerated. The collared peccary of Texas (*Pecari angulatus*) has frequently been bred in the National Zoological Park.

THE CAMEL TRIBE

Whether any of the wild camels of Central Asia are really native wild animals or not is a moot question. Many naturalists believe that the Bactrian or two-humped camels now found in a wild state in remote parts are merely the feral descendants of stray domestic animals, after the manner of the wild Spanish horses formerly occurring in the southwestern United States. Camels are popularly associated with hot barren deserts, but the two-humped camel (*Camelus bactrianus*) is used in great numbers on the bleak steppes of Siberia, where the temperature at times is anything but moderate. Great caravans of these famous beasts of burden carry the rough felt and other products of the desert tribes and Mongolians northward to the Siberian Railway. The specimens of this species kept in the park are much more hardy than the Arabian camels.

The dromedary, or Arabian camel (*Camelus dromedarius*), is the species so much used as a pack and saddle animal in northern Africa. A drove of 75 camels of this species was introduced by the United States Government from Smyrna into the Southwestern States in 1856, and others were obtained 10 years later. Escaped animals from these introductions frequented the Arizona deserts in a wild state up to about 1893, when the last survivors were killed. Both species of camels have bred in the park.

From the evidence provided by fossil remains, America was at one time inhabited by many camels and camel-like animals, which occupied the country even so far to the north as the arctic portions of Alaska. The sole remaining species are the forms of the genus *Lama* found in South America.

The wild llama, or guanaco (*Lama guanicoe*) is found in herds from Ecuador to southern South America and ranges from sea level in Patagonia to high altitudes in the Andes. It differs conspicuously from the Old World camels in its small size and the absence of humps on the back. It was early domesticated by the natives of South America and two general types or breeds have been evolved—the domestic llama, kept chiefly as a beast of burden; and the alpaca, bred for its wool-like coat. The wild guanacos are of uniform coloration, but the domestic llama and alpaca are variegated brown, white, and black, or of solid colors.

All of the forms of the llama breed freely in the National Zoological Park, and the young are graceful, attractive animals, much admired by visitors.

The vicuña (*Lama vicugna*) is a smaller species than the guanaco, with a distribution limited to the higher Andes of Bolivia, Ecuador, and Peru. It has never been domesticated, but the animals in the park have been gentle and do not seem to suffer from confinement

in small yards. With the llama already in use and bred into different varieties, there was little reason for special effort by the natives to add this high mountain species to their list of domestic stock.

THE DEER PADDOCKS

No less than 15 species of the deer family (Cervidæ) are usually shown in the National Zoological Park. Deer are attractive exhibition animals and with proper care do very well in captivity. It is often possible to show small breeding herds in large open paddocks, where the animals present a natural and pleasing appearance.

The members of the deer family are of special interest to sportsmen, and to the average visitor are a never ceasing source of wonder on account of the annual shedding of the antlers. These antlers are present in the males of most of the species of true Cervidæ, and are well developed in the females of the caribou and reindeer. They are dropped annually after the rutting season, and during renewal are covered with the "velvet" which is later worn off when the antlers are polished by the animals' rubbing them against trees and rocks. The growth of the new antlers is astonishingly rapid, and in Siberia the maral, or native elk, is kept in large numbers for the antlers alone. These are sawed off while in the velvet and shipped in great quantities to Mongolia and China, where they bring good prices for medicinal purposes.

The most stately and conspicuous of the American deer is the wapiti, or American elk (*Cervus canadensis*). Although less in size than the moose, he is of more graceful and handsome proportions. This fine animal once ranged over much of the United States, but is now restricted to a few localities where the species has been carefully preserved. The greatest numbers are to be found in the Yellowstone National Park and the surrounding country, whence numbers have in recent years been shipped into several Eastern States which were, years ago, inhabited by the species. The elk range in the Zoological Park is situated along the eastern border, between Rock Creek and the boundary fence. The animals breed freely in this place and are maintained in splendid condition.

Near relatives of the American elk are the Bedford, or Manchurian stag (*Cervus xanthopygus*), the Kashmir deer (*C. hanglu*), and the red deer of Europe (*C. elaphus*). These are all represented in the park by fine breeding herds. The Bedford deer and the Kashmir deer were presented to the park by the Duke of Bedford from his herds at Woburn Abbey, England.

The common white-tailed, or Virginia deer (*Odocoileus virginianus*), the mule deer (*O. hemionus*) of the Rocky Mountain region and the black-tailed deer of the Pacific coast (*O. columbianus*) all do well in the park, and breeding herds are shown in large, open yards.

The Virginia deer is probably the best known big game animal in the United States. It ranges, in some of its geographical forms, from New Brunswick to South America. In addition to the common form of the eastern United States, one of the tropical species, the beautiful Panama deer (*O. chiriquensis*), is on exhibition. It is greatly to be regretted that the quarantine regulations now in force against hoofed mammals from South America make it virtually impossible to import and exhibit any of the remarkable and characteristic species of deer native to that country. These are of types very different from the deer of other lands and should be shown in the park.

Among the Old World kinds none are more beautiful and attractive than the fallow deer (*Dama dama*). These deer are spotted in summer, but the winter coat is of uniform color; the antlers are comparatively large and somewhat flattened or palmate. This species is a native of the Mediterranean region, but has long been introduced in western Europe where it lives in a wild or semidomestic state. Blackish and light colored varieties have been bred, and specimens of the former are usually to be seen in the park herd.

The axis deer or chital (*Axis axis*) is spotted at all seasons. It is a native of India and a closely related form is known from Ceylon. The antlers of this deer are long, slender, and of three tines—a prominent brow tine and one fork above. Another spotted oriental species shown is the hog deer (*Hyelaphus porcinus*). This is a more sturdy species than the axis, but is only about 26 inches high at the shoulder.

The large group of oriental deer known as the rusine species is represented in the park by the sambar (*Rusa unicolor*). Numerous species of *Rusa* occur throughout southeastern Asia and on many of the East Indian Islands. Most of the larger islands of the Philippine Archipelago have their distinct species, sometimes two. The antlers are normally stout and of three tines, but in some species are very small and with elongated pedicles.

The park possesses a fine herd of the barasingha, or swamp deer of India (*Rucervus duvaucelii*). This striking species thrives in the large paddocks provided for it. Its antlers are large, sweeping, and many-tined. A near relative is the Burmese deer (*R. eldi*). The little Japanese deer (*Sika nippon*), one of the most satisfactory species for park purposes, also is shown.

A small herd of reindeer (*Rangifer tarandus*), imported from Norway, may be seen in a large paddock near the buffalo range. These deer are particularly interesting because of the fact that both sexes grow antlers. The American representative of the reindeer is the caribou, found in the northern parts of the continent.

THE ANTELOPES

Asia and Africa are the present-day homes of a great group of bovine animals known as the antelopes. In Africa, especially, this group offers the most astonishing diversity and the species range in size from the tiny dik-dik to the giant eland. There are brilliantly colored forest species and plain colored desert forms; solitary species and others which graze in great herds. Frequently these herds are composed of animals representing a number of distinct genera. The true antelopes, like the cattle, have hollow horns which grow and are retained throughout life—as opposed to the solid, deciduous antlers of the members of the deer family.

Among the African antelopes in the park are the great, gentlefaced East African eland (*Taurotragus oryx livingstonii*), first presented by the Duke of Bedford, and now regularly breeding; the sable antelope (*Egocerus niger*), with his long, bowed horns, and the beautiful blesbok (*Damaliscus albifrons*), both of South Africa; the lechwe (*Onotragus leche*), related to the water buck; the rather spectacular and very noisy wildebeest or white-tailed gnu (*Connochaetes gnou*), and his much rarer relative, the brindled gnu (*C. taurinus*). With the exception of the elands, which have large paddocks to the north of the elephants, all of these African species are kept in the antelope house, where such as need them have heated quarters in winter and all have pleasant yards for summer range.

The Asiatic antelopes shown include the fine, large species known as the nilgai (*Boselaphus tragocamelus*) and the small black buck (*Antelope cervicapra*). Both of these species are restricted to peninsular India. The females of each are without horns and differ markedly in color from the males. The black bucks thrive in the National Zoological Park in outdoor paddocks with unheated shelter, and both species regularly breed.

The American antelope or pronghorn (*Antilocapra americana*) belongs to a separate family. It was formerly abundant on the western plains, but is now found in only a few scattered localities. This animal differs considerably from the true antelopes. The horns are shed annually, only the bony core persisting throughout life. The pronghorn is especially hard to keep in eastern zoological gardens and specimens are not always on exhibition in Washington. It is a matter of great satisfaction that one example was kept in the park for so long a period as five years.

GOATS AND SHEEP

Goats and sheep are native to many sections of the northern parts of both hemispheres, and many and diverse wild species are known. They are closely related, and forms of each have long been domesticated and bred along lines of most utility.

The Alpine ibex (*Capra ibex*) was formerly common in the mountainous parts of central Europe, but is now rare over much of its former range. Related forms are found in the mountains of Spain, northern Africa, and eastward to central Asia.

The tahr (*Hemitragus jemlahicus*) of the Himalayas and the aoudad, or Barbary sheep (*Ammotragus lervia*) of northern Africa, are species which connect in many features the true goats with the sheep and make it difficult to draw a sharp distinction between the groups. The male tahr is an animal of striking appearance, with his heavy collar and mane of long, shaggy hair reaching to his knees. He is an animal of the forested mountains and an exceptional climber and jumper. The aoudad is another animal that attracts great attention in the Zoo. Although lacking the regular beard of the goat, he has extraordinarily developed hair on the neck and fore limbs, and an upright mane extending to near the middle of his back. The aoudad is also at home on the steep slopes that are included within his paddocks.

The Rocky Mountain sheep, or bighorn, which is known in some of its geographical forms in western North America from Alaska to Mexico is well represented in the park by five specimens of the typical form (*Ovis canadensis*) received from the Dominion parks branch of the Canadian Government. These sheep came from the protected area included within the Rocky Mountain Park and were shipped from Banff, Alberta. Several young have been reared. The Arizona race (*O. c. gaillardi*) is also shown.

One of the most beautiful of wild sheep on exhibition is the moufflon (*O. musimon*), native to Corsica and Sardinia. It is much smaller than the American wild sheep and is even smaller than a good-sized domestic sheep, but it is a trim creature and is handsomely marked.

ROCKY MOUNTAIN GOAT

The Rocky Mountain goat (*Oreamnos americanus*), which is still common in parts of Alberta and British Columbia, was formerly abundant in the rugged mountains from Alaska to Washington, Idaho, and Montana. It is one of the most peculiar of American big game animals and has no nearer living relatives than the chamois, serow, goral, and takin, all found in the Old World. The hair is white or creamy white, and in the winter grows long and shaggy. The horns, which average longest in the female, are shiny black with smooth, sharp tips. Mountain goats are not especially alert, and are easily stalked, but their natural range is in the most difficult mountains and a successful hunt usually requires time and endurance. The mountain goats on exhibition were presented by

the Canadian Government and came from Banff, Alberta. Several young have been born in the park.

THE MUSK OX

Specimens of the Greenland musk ox (*Ovibos moschatus wardi*) were first received at the National Zoological Park in 1922. The musk ox is now found only in the barren Canadian Arctic and in Greenland, but, as shown by its fossil and sub-fossil remains, it formerly inhabited Alaska and northern Europe and Asia. Its range has been greatly restricted within historic times, great numbers of the animals having been killed by explorers of the North. Present-day protection by the Canadian and Danish Governments will doubtless save the species from actual extermination, and plans are even being made to attempt the semidomestication of some of the remaining herds for commercial purposes. Owing to the nature of the animal its protection should not be difficult, and it should prove a valuable addition to the domestic animals of the northern treeless wastes. The musk ox is usually considered the only representative of a special subfamily of bovine animals.

BISON, YAK, AND THEIR ALLIES

The herd of American bison (*Bison bison*) maintained in the National Zoological Park has been brought together from various sources. It is now kept at approximately 17 head, and the surplus stock is exchanged to other parks and bison reservations. There are now many places where bison herds are kept and carefully protected and bred so that all danger of the extinction of this famous American ruminant is past. The number of animals is increasing yearly under the direction of the American and Canadian Governments and the American Bison Society; new herds and reservations to accommodate the surplus animals have been created.

The yak (*Poëphagus grunniens*) is found in a wild state in the very high mountains of central Asia, in Ladak, Tibet, and Kan-su, where it lives at altitudes varying from 14,000 to 20,000 feet. The color of the wild stock is a blackish brown. Tame, semiwild, and feral herds ranging northward into the Altai Mountains at much lower altitudes, even to the Siberian slopes of the Little Altai, are of mixed colors, black, brown, gray, and white. Both sexes normally have horns; those of the male oftentimes are of great length. The natives of central Asia say that the yak is not successfully kept below 4,000 feet in that region. The animals in the Zoological Park, at what is practically sea level, do not seem to suffer from the low altitude, and frequently breed.

The Indian water buffalo (*Bubalus bubalis*) has been domesticated and introduced into southern Europe, parts of Africa, eastern Asia, and many of the East Indian islands. The examples on exhibition came from the Philippine Islands, where the animal is called the carabao, and is in quite general use. This buffalo sometimes grows to an immense size, and specimens have been reported that were as high at $6\frac{1}{2}$ feet at the shoulder. The horns vary in the several wild races and domestic breeds and are sometimes very large, curved in a crescentic form, or directed widely outward, when they may measure nearly 6 feet from tip to tip. In the British Museum is a pair of horns which measure $77\frac{3}{8}$ inches in length. Smaller related species are native to Celebes and Mindoro.

THE PRIMATES

The order of mammals known as the Primates includes the lemurs, monkeys, apes, and man. The lemurs are mostly nocturnal animals and are, so far as living forms are concerned, not closely related to the other Primates. In some species the tail is very long; in others it is wanting entirely. In the present age the lemurs are confined to Africa, the oriental region, and to Madagascar and neighboring islands. Many of the species are confined to the latter region.

The other Primates are usually divided into several families. The principal groups are the marmosets, small species often of brilliant coloration and silky coat, confined to tropical America; the remaining American monkeys, of great variety in size and characteristics, and of an uncertain number of families; the Old World monkeys, all rather closely related as compared with the great diversity shown by the American species; the anthropoid apes, including the gorilla, orang-utan, chimpanzee, and gibbon; and finally man.

While the majority of the Primates kept in the park are exhibited in the monkey house, several outdoor yards and shelters are provided for such species as endure our winters without heated quarters, and the chimpanzee and the orang-utan make their winter homes in a specially prepared corner of the lion house.

THE GREAT APES

Of the four anthropoid apes, gorilla, chimpanzee, orang-utan, and gibbon, all but the first named have been represented in the park collection. No animal in the park attracts more attention from visitors than "Soko," the chimpanzee (*Pan satyrus*). "Soko" reached the park in September, 1915, from the forests of the French Kongo. He was then about $3\frac{1}{2}$ years old and weighed only 38 pounds. During the autumn of 1916, or when about $4\frac{1}{2}$ years old, he lost his milk teeth, and since the permanent teeth have developed

his growth has been much more rapid than before. On September 1, 1918, he weighed 85 pounds, and in 1923 his weight was about 120 pounds. While still a young animal he was taught by his keepers to take his formal meals seated at a table, and this he did daily up to recently, much to the joy of the children who crowded about his cage. Although still very good tempered, he has grown too powerful to be trusted with safety and his training has been discontinued. "Soko" does all sorts of unexpected tricks and is a creature of extreme moods. At times he is very grave and serious, and again, especially if he has an appreciative audience, he is bubbling over with the joy of life and spins round and round on his back and shoulders or turns somersaults repeatedly. The chimpanzee is found only in the forested areas of Central Africa, from the western coast eastward to the region of the great lakes. A number of different forms are recognized by naturalists.

OLD WORLD MONKEYS

With few exceptions the Old World monkeys are all exhibited in the building known as the monkey house. The exceptions are hardy species which seem unmindful of our coldest winter weather and thrive in unheated outdoor cages, where they are provided of course with snug and comfortable sleeping quarters. These "fresh-air" monkeys include the Barbary ape (*Simia sylvanus*) of northern Africa and Gibraltar; the rhesus monkey (*Macaca rhesus*), a social species of northern India; the brown macaque (*Macaca speciosa*), of Upper Burma and Cochin China, in which the tail is nearly obsolete; the Japanese monkey (*Macaca fuscata*), a long-furred, naked-face, short-tailed species; and the chacma (*Papio porcarius*), a South African baboon of large size and great strength. A full grown male of this powerful baboon is said to be a match for a leopard; and as the animals usually live in troops, so great a number as 100 being sometimes associated in this manner, they at times are responsible for great depredations to crops, and have been known to kill lambs and other stock.

In the monkey house and the annexed outdoor yards for summer use are shown a variety of the Old World species. A number of forms of macaques, related to those mentioned above, are usually here. These include the bonnet monkey (*Macaca sinica*), a native of southern India; the pig-tailed monkey (*M. nemestrina*) of the Malay region; the Burmese macaque (*M. andamanensis*); the Moor macaque (*Cynopithecus maurus*) from Celebes; and others. The mangabeys, a tropical African group of long-tailed, forest-loving monkeys, are represented by the sooty mangabey (*Cercocebus fuliginosus*), an obscurely colored but very active species; the black

mangabey (*C. aterrimus*); Hagenbeck's mangabey (*C. hagenbecki*); and the white-collared species (*C. torquatus*).

The guenons form the largest group of the Primates and exhibit remarkable diversity in coloration and color pattern. They are attractive and very interesting monkeys with slender bodies and long limbs and tails. Some of the species are oddly and brilliantly colored. The group includes about 80 forms and is native to Africa; but two species (the mona and the green guenon) have been introduced into the West Indies and are perfectly established on some of the islands. Attractive species of this genus shown in the monkey house are the mona (*Lasiopyga mona*), the vervet (*L. pygerythra*), the green monkey (*L. callitrichus*), and the roloway (*L. roloway*), the latter an especially beautiful form with glossy, blackish coat and a long, white beard. The patas monkeys (*Erythrocebus patas*) are near relatives of the guenons but are larger animals, more at home on the open country than in the forests. The general coloration is red.

Baboons shown, in addition to the chacma, mentioned above, are the yellow baboon (*Papio cynocephalus*) of northern Africa; the Hamadryas baboon (*P. hamadryas*), a large, powerful Abyssinian species which lives in herds of up to 300 in number in the rocky, waste country; the mandrill (*P. sphinx*), a West African species with an enormous head and long snout; and the drill (*P. leucophaeus*) of Cameroon. An albino specimen of the East African baboon (*P. ibeanus*) attracts great attention. It was purchased in Mombasa in 1914 by Mr. H. N. Sclater, who presented it to the park.

AMERICAN MONKEYS

The American monkeys and marmosets are of great variety and are found throughout most of tropical America, north into Mexico. In parts of equatorial South America many species occur in the heavily forested river valleys. They are, unfortunately, much more difficult to keep in captivity than are most of the Old World monkeys, and only a few species are successfully maintained in zoological gardens. The capuchins, the exception to the rule, are the commonest hand-organ monkeys and are familiar to all. Three species of these are regularly shown, the white-throated capuchin (*Cebus capucinus*), the brown capuchin (*C. fatuellus*), and the weeping capuchin (*C. apella*). Geographical races of the first range northward into Nicaragua. Among the many rare and unusual animals collected by the Mulford Biological Explorations of the Amazon Basin, and presented to the park in 1922, are two additional species, the pale capuchin (*C. unicolor*) and Azara's capuchin (*C. azarae*), both from Bolivia.

The spider monkeys are remarkable for the highly developed prehensile tail, which is constantly used as a fifth hand. They are among the most perfectly arboreal of mammals and exhibit the greatest agility in their movements throughout the tree tops. Numerous species are known and the range of the genus extends northward well into Mexico. The species most commonly exhibited in the park is the gray spider monkey (*Ateles geoffroyi*). Various species of squirrel monkeys and marmosets are shown from time to time.

THE LEMURS

Although several groups of lemurs are known from Africa and the oriental region, the species included within the typical genus *Lemur*, and known as "true lemurs," are confined to Madagascar and neighboring islands. They have a foxlike face and muzzle and a long tail. The numerous species are essentially arboreal and many of them are strikingly colored. The mongoose lemur (*Lemur mongoz*) is a noisy, gregarious species, noted for its agility in trees. In addition to this species, the black lemur (*Lemur macaco*) and the fulvous lemur (*L. fulvus*) are shown.

THE GNAWING MAMMALS

Among the gnawing mammals are included two very distinct orders—the Rodentia and the Lagomorpha. The latter order is made up of the hares, rabbits, and pikas, while all the other existing rodent-like forms are members of the order Rodentia. The vast majority of rodents are small creatures, like the mice, rats, and squirrels; but the order includes some very sizable living animals—the porcupine, beaver, and capybara, while an extinct South American member of the group was as large as a hippopotamus. The most characteristic features of the Rodentia are the complete absence of canine teeth and the great development of the incisors which, owing to their persistent growth and the presence of hard enamel chiefly on the anterior surface, are worn by use to a chisel-like edge. There is always a considerable space on the jaw between these cutting teeth and the molariform grinders.

Until some special means for the exhibition of living examples of the smaller rodents and lagomorphs can be devised, the collection must be mainly restricted to the larger forms. The common gray squirrel and the cottontail rabbit roam wild within the borders of the park. Among the gray squirrels will be seen numerous black or blackish examples. These are descendants of black squirrel stock introduced in the park a number of years ago from southern Ontario.

Other members of the squirrel family shown are the prairie dog (*Cynomys ludovicianus*) and various species of ground squirrels and marmots. The prairie dogs have an inclosed area near the eland yards where they live the social village life so characteristic of the species. Numbers of young are born and reared each year. During the coldest winter weather the prairie dogs hibernate, but in nice weather they are always to be seen about the "dog town."

Two aquatic rodents, the American beaver (*Castor canadensis*) and the coypu (*Myocastor coypus*) of South America enjoy the running stream above the sea lion pool. The beavers have an extensive yard and have dammed the stream in true beaver fashion so that the resulting lake offers them the most natural surroundings. They are best seen in the late afternoon. The coypu, or nutria, is thoroughly at home in the water, and the teats of the female are placed high on the side of the back so that the young are able to nurse without diving. The fur is valuable for many purposes but is chiefly cut and used in the manufacture of hats. As many as 500,000 skins have been exported from South America within a single year.

The African porcupine (*Hystrix africaustralis*) and the Malay porcupine (*Acanthion brachyurum*) are splendid species with quills far longer than those of the American porcupines.

Among the attractive rodents found only in tropical America are the families Caviidæ, Dasyproctidæ, and Chinchillidæ. Many species are peculiarly adapted to zoological park life, are showy animals, and breed regularly in captivity. The guinea pig (*Cavia porcellus*), so familiar to children, is bred in large numbers. The paca (*Cuniculus paca*), one of the larger rodents, has a brown body well marked with whitish spots. He is related to the agouti (*Dasyprocta*) of which a number of species are regularly kept. Some of the species of agouti are brilliantly marked; a most striking species is the hairy-rumped agouti (*D. prymnolopha*). One of the most beautiful forms, the Trinidad agouti (*D. rubrata*), first received from Hon. Henry D. Baker, has twice bred in the park. Agoutis range north into Mexico and on several of the West Indian islands. They are hunted with dogs by the natives, and are said to be almost as cunning as a fox. Eight species of agouti were on exhibition at one time in 1923.

The capybara (*Hydrochærus hydrochæris*) is a native of South America, north to Panama. This species is very fond of marshy tracts and is an expert swimmer. The specimens now on exhibition were received from Venezuela and British Guiana. Capybaras sometimes grow to more than 4 feet in length; they are thick-set animals and although easily the largest of the existing rodents are gentle, inoffensive, and easily tamed.

THE CARNIVOROUS MAMMALS

Two distinct orders of this group are now recognized by mammalogists. The Carnivora proper, or Fissipedia, include the families of cats, civets, hyenas, dogs, raccoons, weasels, and bears, with their allies. The order Pinnipedia is comprised of the seals, sea lions, and walrus. While there is immense variety in the dentition of carnivorous mammals, as a rule the teeth are highly developed for the process of tearing and cutting flesh or the crushing of bone. Some species are far from "carnivorous," and subsist chiefly upon fruits and insects. The black and brown bears are good examples of this latter type, but most carnivores do at times eat more or less of vegetable food. Some of the smaller species are largely insectivorous.

The largest of living carnivores is the great brown bear of Kadiak Island, Alaska; the smallest, the least weasel of the boreal regions of both continents.

The Pinnipedia are readily divided into groups typified by the hair seals or harbor seals, the sea lions, and the walrus. The hair seals have no external ears and the hind limbs are so placed and modified as to be useless for walking on land. The feet, or hind "flippers," protrude backward and are used in the nature of a tail in swimming. The common harbor seals of both coasts belong to this group. The sea lions, or sea bears, have external ears, and the hind limbs are functional for walking on land. This group includes the famous fur seal as well as the species of sea lions. Peculiarities of the skeleton point to a very ancient separation of these two groups of seals, and they are not so closely related as would appear from their external appearance and habits.

THE CATS

Specimens of the larger members of the cat tribe are usually kept in all menageries and are favorite animals with the public. The collection in the National Zoological Park includes beautiful examples of many of the most interesting and showy species. The larger kinds are shown in the lion house.

The African lion (*Felis leo*) ranks foremost in popular interest. The adult male is a magnificent beast with massive head, a full mane, and a long tufted tail; he presents a most imposing appearance. Lions thrive in captivity and develop much finer manes of softer, more luxuriant hair on the neck and shoulders than is usual in wild animals. Lions brought from the high and comparatively dry plateaus of East Africa develop much darker coats in the Zoological Park than in a natural state. This is supposed to be due to the more



WOOLLY MONKEY



ORANG-UTAN



SOOTY AGOUTI



LION



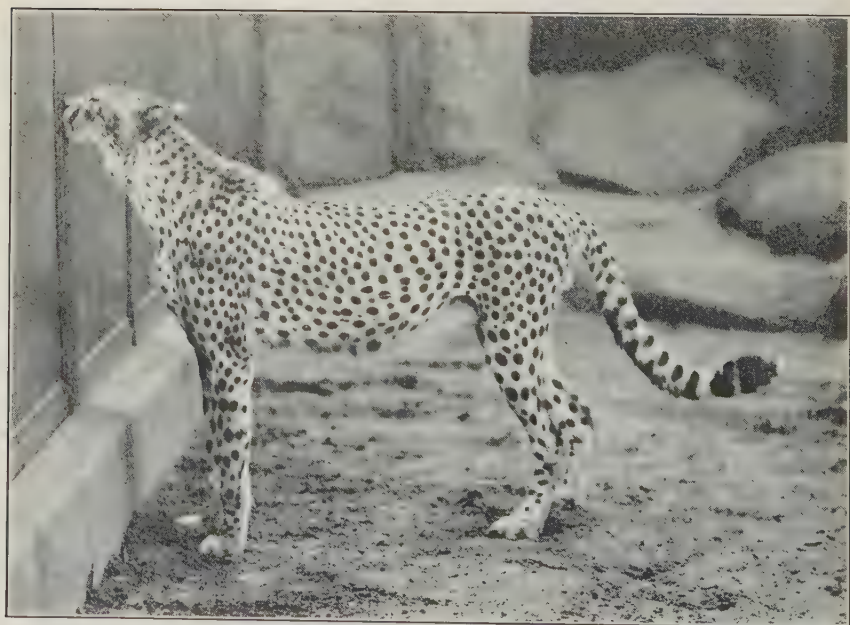
MANCHURIAN TIGER



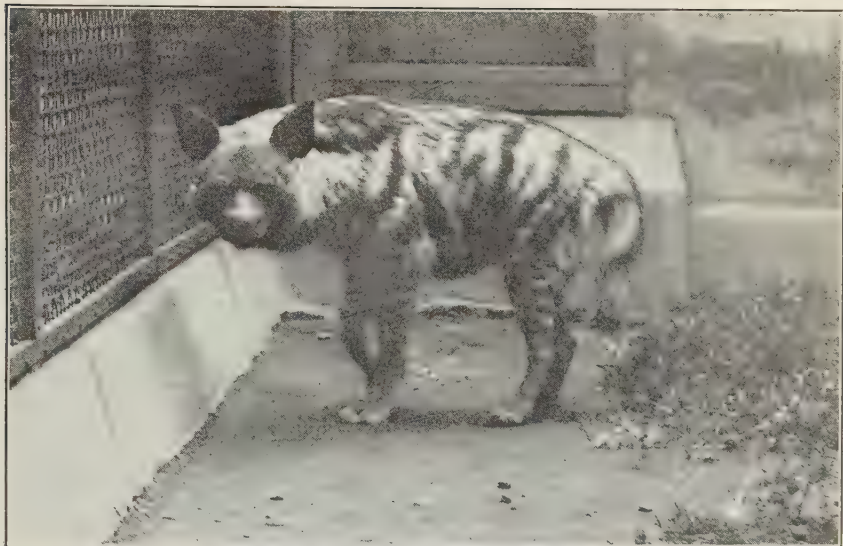
LEOPARD



JAGUAR



AFRICAN CHEETAH



STRIPED HYENA



GREAT-EARED FOX



IN THE RACCOON TREE



OTTER



EUROPEAN BROWN BEAR AND CUBS



CALIFORNIA SEA LION



KANGAROO WITH YOUNG IN POUCH

humid atmosphere of Washington. The mane of the lion is not fully developed until the animal has reached a very mature age, and the numerous "adult" lions without manes shot by sportsmen prove to be in reality fully grown but immature animals. In the series of over 100 lions preserved in the National Museum the full-sized but maneless males are invariably the younger ones, as shown by the condition of the sutures of the skull and the condition of the teeth. The mane grows much more rapidly in park specimens and appears fully developed at an age when wild lions would still be "maneless." Numerous geographical races of the lion are known, and the range of the animal extends into western India. Within historic times the species was wild in southeastern Europe.

The tiger, the lion's rival in size, strength, and popular interest, is an inhabitant of Asia, where it ranges through its various forms from southern Siberia to Java and Bali, and westward to Persia. It is absent from the greater part of the highlands of the central parts of the continent but has been killed so far north as Sakhalin Island on the coast and the northern slopes of the Altai in central southern Siberia. It is best known from Korea and Manchuria, the Amoy region of eastern China, Malaya, and India, each region furnishing a special type. The Bengal tiger (*Felis tigris*) is the best known form in menageries. It has a short coat and is a very inferior animal to the splendid Manchurian tiger of the north (*Felis tigris longipilis*). The Manchurian tiger is common in parts of Korea where it is usually hunted on the snow in winter. Both the Bengal and Manchurian tigers are represented in the Zoological Park collection of the great cats, and the numerous points of difference between these two forms are readily seen. The most beautiful of all the tigers, the Amoy species, has never been shown; although skins regularly reach the market, living specimens are rarely obtainable. The same may be said of the very distinct Persian form. The Malay and Sumatra tigers are frequently seen in zoological gardens and specimens of the former lived for many years in the National Zoological Park.

The leopard (*Felis pardus*) of Asia and Africa and the jaguar (*Felis onca*) of America are spotted cats with many superficial points of resemblance. The leopard is a less stocky animal than the jaguar, though he exceeds in size many of the smaller specimens of the American species. Like the lion and the tiger the leopard is divided into several subspecies or geographical races. Both the African and Asiatic forms are kept in the park. The jaguar ranges from Argentina northward to Mexico, and is sometimes killed in the wilder parts of Texas and New Mexico. Unlike the puma, or mountain lion, it is at times very destructive to cattle. The smallest

jaguars come from northern South America and the largest form inhabits Paraguay and southern Brazil. The great difference in size between specimens from these two regions is remarkable. Skulls of adult male specimens of the Paraguay jaguar exceed in measurements the skull of the largest Korean tigress recorded.

The snow leopard (*Felis uncia*) is one of the most beautiful of the larger cats. It inhabits the mountains of central Asia. The specimen on exhibition in the park lives without artificial heat the year around and enjoys the colder winter weather.

The puma, known in the Western States as the mountain lion and in the south as the panther, has an extensive distribution from British Columbia to Patagonia. It was formerly common in the Eastern States, but is now exterminated over much of its original range. In parts of Florida and especially in the canebrake regions of Louisiana, panthers are still found. In the Bear Lake cane of northeastern Louisiana the animal was almost common a few years ago and doubtless is frequently found to this day. The mountain lion of the Rockies (*Felis hippolestes*) and the paler colored form from Arizona (*Felis azteca*) are both exhibited in the park. In parts of the West and Southwest the mountain lion is still found in numbers, and in particular localities is so destructive to colts that it is almost impossible to raise horses on the open range. There are several authentic instances of the mountain lion's attacking man without the slightest provocation; but considering the wide distribution of the animal and its comparative abundance, these must be considered exceptional traits of habit.

The ocelot (*Felis pardalis*) is a smaller spotted and blotched American cat, common in the Tropics and regularly found in southeastern Texas. It is a handsome species which varies greatly in color and markings. The Canada lynx (*Lynx canadensis*) is a larger, tufted-eared relative of the common bobcat, or wildcat, of the United States. It is found over much of the wooded parts of British America and Alaska and into the Northern States and Rocky Mountain region of the West. It is much sought by the trapper and during the periodical abundance of the northern hare becomes very plentiful, so that large numbers are captured.

The bay lynx, or bobcat (*Lynx rufus*), is the wildcat commonly found in unsettled portions of the United States. Like other species of wide distribution it is divisible into numerous geographical forms. One of the handsomest of these is a richly colored race from the humid coast region of the Northwestern States.

The clouded leopard (*Neofelis nebulosa*) is another of the more handsome cats. It is smaller than the snow leopard, but is quite as beautifully marked. It lacks the fine form of the head and face of the snow leopard, however, and belongs in a separate genus. The

canine teeth are exceptionally long. The clouded leopard has quite an extensive distribution and is found from the mountains of northern India to the islands of Java, Sumatra, and Borneo.

The cheetah, known also as the "hunting leopard," is sometimes trained to hunt the antelope and other game. Long limbed and slender, with high rounded head, and with claws less retractile than in the other cats, he has many points of resemblance with the dog; this resemblance is not confined to external appearance, but is found also in the muscles. A pair of African cheetahs (*Acinonyx jubatus*) was brought over in 1913 by the head keeper of the park from the Government Zoological Garden, Giza, Egypt. They have developed splendidly here and may be considered one of the most important exhibits.

CIVETS AND HYENAS

The civet cats and their allies, the mongooses, genets, and palm civets comprise the family Viverridæ. They are of diverse types and are native to the Old World, but one species of mongoose has been introduced in some of the West Indian Islands where it has nearly exterminated many of the native species of birds. Regulations against the introduction of this pest into the United States are rigidly enforced, but a specimen was, nevertheless, killed in Kentucky in 1920. How the animal came to be there is not known. It is greatly to be hoped that the mongoose will never get a foothold in any part of the United States, as the practical extermination of many of our finest ground-nesting game birds would surely follow its introduction.

The spotted hyena (*Crocuta crocuta*) is the commonest African species of the family Hyænidæ. He is a large, powerful brute with jaws and teeth specially developed for crushing bones. The specimen kept in the lion house is a great pet and is excited to supreme content by a little attention. Unlike the great cats, he pays not the slightest attention to bones in the meat fed to him, but crushes even the largest as easily and rapidly as if he were eating much softer food. A smaller species, the striped hyena, inhabits India and northern Africa, and a much rarer kind, the brown hyena, or "strand wolf" (*Hyæna brunnea*), is confined to parts of Africa. Hyenas are essentially carrion eaters and are largely nocturnal in habits.

The aard-wolf (*Proteles cristatus*) is related to the hyenas, but is a much smaller animal with much less powerful teeth. The teeth, in fact, are so reduced and simplified as to be of very little use, and the animal feeds very largely upon termites and other insects. The aard-wolf inhabits Africa from Nubia to the Cape. It is very rarely seen in collections of living animals. The specimen in the National Zoological Park is on exhibition in the antelope house.

THE DOG FAMILY

This interesting group of mammals includes the dog, wolf, fox, jackal, and their numerous relatives. It is one of the best-known families in a popular way, but the exact limits of the genera and species are matters not yet thoroughly worked out by any zoologist.

The true wolves were formerly abundant animals over much of the Northern Hemisphere, and, although exterminated by man in many regions, still persist in numbers in some well-inhabited areas. Although long since gone from the British Islands, they are found to this day in numerous parts of continental Europe and are abundant in the less settled portions of central Asia. In North America wolves formerly roamed in large packs over the great game fields and were especially numerous throughout the bison country. The northern "timber wolf" and the "buffalo wolf" of the great plains are powerful beasts and are able to take down our largest animals. The wolves of the Southern States are of less bulk and some species are barely larger than the coyote.

The wolf of the northern Rocky Mountain States (*Canis nubilus*) varies greatly in color, as usual with the American species. Among the specimens in the park are some of the typical "gray wolves" and some very dark, almost blackish examples. Many young wolves of this species have been reared in the park. A specimen of the timber wolf (*C. occidentalis*) from the upper peninsula of Michigan is also shown. This is the wolf of the great forests of northern United States and Canada.

The coyote of the northern plains (*Canis latrans*) is a large species approximating some of the smaller wolves in size. It ranges east to Wisconsin and western Indiana, where it is frequently confounded with the timber wolf; old hunters and trappers often fail to distinguish between the animals. In some localities it is called the brush wolf by those who recognize the difference between it and its larger and more powerful relative. Numerous other species and subspecies of the coyote are found in the Western States and in Mexico. The coyote is structurally closer to the Old World jackal than to the big wolves, and takes the place of the jackal in the American fauna.

The red fox (*Vulpes fulva*) is very common in parts of the North, but is rare in many of the Southern States. In the boreal regions of Canada and the northern United States it takes on a splendid coat and the fur is of considerable value. The cross fox and the black or silver fox are color phases of this species and examples of each are sometimes found in litters of red foxes. Both phases occur most frequently in definite geographic areas, however, and in some western localities the cross fox coloration is the common condition. Silver

foxes are now bred in confinement and the skins frequently bring enormous prices in the fur market.

The swift, or kit fox (*Vulpes velox*) is an inhabitant of the open areas of the West and is found in many of the most arid deserts. A number of species and races are recognized by mammalogists. The fur has no real value.

The common gray fox abounds in many parts of the United States and Middle America. Unlike the red fox, it is a good climber and if pursued by dogs readily takes to trees. The common eastern species (*Urocyon cinereoargenteus*) maintains itself in well-settled communities and is sometimes known by the misnomer of "silver-gray fox." In localities where it is not often taken, the capture of a specimen frequently excites the trapper to the belief that he has a specimen of the real prized and valuable silver fox. The genuine silver fox, mentioned above as a color phase of the red fox, is chiefly black, with more or less white hair mixed in the pelage; whereas the gray fox is always gray and rufous, with a blackish stripe along the upper surface of the tail. The fur of the gray fox is comparatively short and coarse, but is of real beauty and is considerably used by the trade. Its value is much less than the fur of the red fox.

A most interesting member of this group is the great-eared fox (*Otocyon megalotis*) of South Africa. What is probably the first specimen of this species ever exhibited alive in America was presented to the park by Mr. Victor J. Evans, of Washington. The astonishing development of the ears is the chief characteristic of this rare fox.

The Eskimo dog is a variety of the common domestic animal (*Canis familiaris*) and, contrary to general belief, apparently is not a direct and scarcely modified descendant of the wolf now found wild in the northern regions. Examination of dozens of skulls of dogs from the ancient Eskimo dwelling sites of northeastern Siberia and from more recent Eskimo tribes fails to disclose any more wolflike characteristics in the bones or teeth than are found in all large domestic dogs. The primitive Eskimo dog skulls are almost counterparts in all characters of the dog skulls found in ancient Egyptian burials and in the pre-Columbian graves of Peru. Domestic dogs have the general wolf type of skull and teeth without admixture of characters derived from jackal, coyote, or any South American member of the dog family; but the animal is of very ancient origin and its actual wolflike ancestor is not for a certainty known.

Another very interesting dog is the dingo (*Canis dingo*) of Australia. It is found in a wild state, and also, it is said, in a semi-domesticated state among the natives of that country. It has been generally believed that the dingo was introduced by man into Aus-

tralia at some early time, but there is some evidence, furnished by fossil remains, that it existed there with some of the extinct marsupials at a period earlier than man is surely known in that region. In color the dingo is usually reddish or rufous-tawny, although individuals lighter or darker in color than the average specimens are known to occur in an apparently wild state. Whatever the true origin of the dingo, it is certainly as truly a wild animal in Australia in modern times as any of the native marsupials or the ratlike rodents.

RACCOONS AND THEIR ALLIES

The common raccoon (*Procyon lotor*) has a special yard near the elephant houses, with a fine tree in which the animals of the colony may be seen sunning themselves in the topmost branches. South American representatives of the coon family, the kinkajou (*Potos flavus*) and the coati-mundi (*Nasua narica*) are also kept in the park. Both of these animals occur northward throughout much of Central America and Mexico, and the coati-mundi has been captured in southern Arizona.

The panda (*Ailurus fulgens*), of the high Himalaya Mountains, is interesting, not only because of its peculiar red, white, and black coloration, but also because it is the only Old World representative of the raccoon family. It is very fond of bamboo, which is provided as a regular part of its diet.

The cacomistle (*Bassariscus astutus*) is a beautiful little animal often called the "ring-tailed cat," "coon cat," or "civet." It is common along the Pacific coast of the United States and southward into the Tropics. It has many structural characters of the dogs and, although usually classified with the raccoons, has been made the type of a distinct family. The fur at times becomes fashionable and many skins are placed on the market.

THE WEASEL FAMILY

This group of highly bloodthirsty mammals includes such diverse types as the weasel, badger, skunk, marten, and otter. The family has an extensive distribution and species are found in most parts of the globe with the exception of Australia and Madagascar.

The American badgers (*Taxidea taxus*) have a fine yard in the park where they can usually be seen in their characteristic occupation of digging in the soil. So active are they in this work that the dirt within the inclosure is constantly turned over and always presents the appearance of a newly spaded garden. The European badgers (*Meles meles*), on the contrary, are rarely seen, as they spend almost the entire day asleep under the straw in a corner of their quarters.

The common skunk of the Eastern States (*Memphitis nigra*), the marten (*Martes americana*), the fisher (*Martes pennanti*), and the mink (*Mustela vison*) are all American species which are essentially nocturnal and attract little attention in their cages from visitors to the park. The neotropical tayra (*Tayra barbara*), on the contrary, is a friendly, active animal always ready to show himself to visitors.

The otter pens, along the stream above the beaver and sea lion pools, offer an attractive show of the home life of animals. Here a pair of American otters (*Lutra canadensis*) have reared their young and the mother with her family can be seen. Otters are very intelligent and playful animals and may easily be made attractive pets. Moreover, since it is practicable to rear them in captivity, the breeding of otters may be made a very pleasant and profitable occupation, as the skins command a fine price in the fur market.

THE BEAR DENS

The park maintains a splendid collection of bears and few animals attract so much attention from the public as do these interesting creatures. The dens are conveniently and pleasantly located on the west side of the main highway through the park where the animals have ideal conditions for comfort and health.

The polar bears (*Thalarctos maritimus*) are confined to the Arctic regions. On the Atlantic coast of America they formerly occurred regularly south to Labrador. White at all seasons, active in the cages and pool, and expert swimmers, the polar bears are great favorites in the park. Contrary to general belief, the polar bears do not particularly suffer from the summer heat of Washington. It is to be remembered that there are many warm days in summer in their native home and that during this season the bears commonly go ashore and subsist for periods almost wholly upon a vegetable diet. During most of the remainder of the year the food of the polar bear consists mainly of the flesh of seals. A polar bear in the park at one time weighed 760 pounds.

The European brown bear (*Ursus arctos*) is the bear usually seen accompanying itinerant street exhibitions. It naturally stands erect on its hind feet much more than do the other bears and is, consequently, much more readily trained for such purposes. Many young of this species have been reared in the park.

The great and confusing variety of bears found in northwestern America has puzzled naturalists since the first discovery of those huge beasts. Some of the brown bears of Alaska, notably those of the Alaskan Peninsula and Kadiak Island, are the largest of all living species and appear to be intimately related to the brown bears

of eastern Asia and to the extinct cave bears of Europe. Several species of the great Alaskan brown bears are shown in the park. One kept for several years weighed at one time 1,160 pounds.

There are splendid examples of the Kadiak bear (*Ursus middendorffi*); the Peninsula bear (*U. gyas*); the Yakutat bear (*U. dalli*), and Kidder's bear (*U. kidderi*) of Cook Inlet.

The grizzly bear (*Ursus horribilis*) is perhaps the most celebrated of all the bears and has the greatest reputation for strength and ferocity. In the early days of the West the grizzly was very plentiful, and no story of adventure in that region was complete unless it introduced the "silver tip" at some point in the tale. Nowadays grizzly bears are rare or completely exterminated over most of their former range in the United States, but are still found in the Yellowstone National Park, from which place most of our specimens come. In the Rocky Mountains of Canada, and particularly in British Columbia, grizzly bears are commonly found. Numerous species and subspecies of grizzlies are now recognized.

The common black bear of North America (*Ursus americanus*) has a very extensive distribution from Alaska to Florida; a number of geographical races are recognized within this area. This animal has persistently held its own in some of the more settled States, and, like the white-tailed deer, with proper protection is in little danger of extermination. The cinnamon bear, a color phase of the black bear, is of most frequent occurrence in certain parts of the West where a geographical race of the common bear is recognized as *Ursus americanus cinnamomum*.

One of the rarest of all the bears is the glacier bear, or blue bear (*Ursus emmonsii*) of the Mount St. Elias Alps, Alaska. It has a beautiful coat of a blue-gray color. The first living specimen of this interesting American mammal ever exhibited in any zoological garden was received at the National Zoological Park in 1917 as a gift from Mr. Victor J. Evans, of Washington, District of Columbia, who secured it from a resident of Yakutat, Alaska. It was captured as a small cub by Indians about the middle of May, 1916, at the head of Disenchantment Bay. The only specimens ever received before this time were a few skins, mostly obtained by fur traders, and several skulls which have found their way into museums.

The Himalayan bear (*Ursus thibetanus*), the sloth bear (*Melursus ursinus*), and the sun bear (*Helarctos malayanus*) are among the foreign bears exhibited.

SEALS AND SEA LIONS

The common harbor seal of the Atlantic coast (*Phoca vitulina*) is the typical species of a large group of "hair seals" inhabiting the ocean of the Northern Hemisphere. It has a wide distribution and is

found on both shores of the Atlantic, ranging well down the coast of the United States. Near relatives are found in the northern Pacific Ocean, in the Caspian Sea, and in Lake Baikal, Siberia. The harbor seal is an interesting creature, spotted in coat, with a little round head, and an inquisitive face.

The sea lion pool, just west of the bear dens, is a popular show place with the public. In it are kept the California sea lions (*Zalophus californianus*). This species, so familiar to visitors to the Pacific coast, is the animal usually seen in shows of trained sea lions. It is a noisy animal, and the bark of the male can be heard for a considerable distance.

Feeding time at the sea lion pool is an exciting occasion. The animals are fed fish, some of considerable size, which are handed or thrown to them by the keeper from the high rocky den at the end of the pool. It is at this time that visitors can best see for themselves what expert and exceedingly rapid swimmers these animals are. A fish thrown anywhere within reasonable distance of one of the sea lions rarely strikes the water, so expert are the animals in catching them.

THE MARSUPIALS, OR POUCHED MAMMALS

These interesting creatures, although in former periods of time having a wide distribution over the earth, are now confined to Australia and America. They are separated from all the other living mammals by many structural characters. The most interesting point from a popular view is the fact that the young are born at a much earlier stage of development than in other mammals, and spend a long period of growth in the marsupium, or abdominal pouch of the mother, where they are firmly attached to the teats. The newly born young of the larger kangaroos are no larger than a baby mouse, but by the time they first look out of the opening of the pouch, some weeks later, they are grown to a point comparable to the ordinary mammals at birth.

The marsupials in America are all opossums or ratlike forms, but in Australia and Tasmania there are marsupials to represent many of the variations found in the mammals of the world—wolf, bear, squirrel, flying squirrel, cat, marmot, rat, rabbit, lemur, ant-eater, and mole are all imitated in superficial points of structure and mode of life.

Marsupials most often seen in collections of living animals are the various species of kangaroos, wallaby, and wallaroo; the phalangers, Tasmanian devil, wombat, and opossums.

The larger species, the great gray kangaroo (*Macropus giganteus*), the red kangaroo (*M. rufus*), and the wallaroo (*M. robustus*) naturally attract the most attention. They are showy, breed well in

captivity, and the young animals, in and out of the pouch, are a never-ceasing wonder to visitors. From the time when the young are first noted moving in the pouch, it is about three months, with these large kangaroos, before the little animal first puts his head out of the opening. Then follows a very interesting and amusing few weeks during which the young is in or out of the marsupium at his pleasure; sometimes with foot or head out in the most grotesque positions. Finally the mother, when the young animal has grown to a considerable size, refuses it further admission to the pouch. These kangaroos sometimes attain a size of over 5 feet for the head and body alone; the added length of the great tail makes the animal appear much larger.

Several smaller species of kangaroos are usually kept in the antelope house. Among the most interesting at the present time are the rufous-bellied wallaby (*M. billardieri*) and the brush-tailed rock kangaroo (*Petrogale penicillata*). The rock kangaroos are at home in rough country rather than in level areas; the tail is less robust than in the other species and is not used as a ground rest when the animal stands erect.

The phalanger (*Trichosurus vulpecula*) is another Australian species, largely nocturnal, and with the habit of playing "'possum" like its American relative. It is not active in the cages and is rather uninteresting in the zoo. The wombat (*Phascolomys mitchelli*) is a powerful, heavy-set brute, with large head and only a short stump of a tail. It is a burrowing animal and is said to live in small colonies. This is an Australian species, but a closely related form inhabits Tasmania.

The Tasmanian devil (*Sarcophilus harrisii*) is as ugly dispositioned a beast as he is displeasing to the eye. Naturally of nocturnal habits he is not often active in the cage. The Virginia opossum (*Didelphis virginiana*) is likewise of such retiring disposition that he is seldom seen. A small relative, called the murine opossum (*Marmosa murina*), is a native of tropical America and occasionally finds its way into the United States as a stowaway in a bunch of bananas.

BIRDS

Birds (class Aves) are often defined as "animals with feathers," and this diagnosis answers every purpose for popular use, since all birds have feathers and no other animals possess them. No class of animals has received so much popular attention and few so much scientific study as have the birds. Almost any single locality offers a large list of species, and the variety to be found during the spring and fall migration makes a study of the birds of any vicinity an interesting and exciting occupation. On account of their great

beauty, interesting characteristics, peculiar coloration, or grotesque appearance, most birds are popular as cage pets and the collections in the Zoological Park are great attractions to the public. The great flight cage near the west entrance, the bird house, the water-fowl lakes, the eagle cage, and numerous smaller inclosures are used to exhibit the birds to best advantage. Each variety is given so far as possible the best conditions afforded by the natural features of the park or the resources available for improvements. No complete systematic arrangement of the birds is, therefore, practicable, but so far as is convenient related birds are grouped together. Twelve or more distinct orders of birds, according to recent schemes of classification, are commonly represented in the park by numerous species, and some of the most conspicuous or interesting varieties of each group will be mentioned here in proper sequence.

OSTRICH-LIKE BIRDS

The existing members of this group (Ratitæ) are, with the exception of the kiwis of New Zealand, all large birds. They are incapable of flight, but are swift of foot and exceedingly wary, and are, moreover, able to defend themselves vigorously with beak and foot. They are keen of sight and, except the cassowary, are inhabitants of open country.

The ostriches are of maximum size for existing birds, a full-grown male sometimes measuring more than 8 feet in height. They are distinguished from all other birds by having only two toes on each foot. The true ostriches are now confined to Africa and the adjacent portions of southwestern Asia, where several species occur. Three of these forms are shown in the park. A specimen of the great Somaliland ostrich (*Struthio molybdophanes*) was presented to President Roosevelt by Emperor Menelik of Abyssinia, and is a magnificent example of this fine bird. A somewhat similar species is the Nubian ostrich (*S. camelus*). The South African ostrich (*S. australis*) is the species most commonly kept on the ostrich farms in the Southwest, where the bird is reared for its feathers. The adult male ostrich is a splendid bird in his black and white plumage, but the females and young males are of a dull grayish-brown coloration.

The ostrich is represented in South America by the rhea, one species of which (*Rhea americana*) is kept in the park. This is a bird of considerably less size than the ostrich; it has three toes, and its feathers are of less commercial importance. Like its African relative, it is an inhabitant of the open country and is found on the pampas of Argentina and on the great plains of southern Brazil and Bolivia.

Australia and the neighboring islands are the homes of a number of ostrichlike birds. The park possesses examples of two of these peculiar types. The common cassowary (*Casuarus galeatus*) is a native of Ceram, but closely related forms occur in New Guinea, Australia, and on other islands. The emu (*Dromiceus novæhollandiæ*) comes from Australia. The birds kept in the park have laid many of the beautiful and characteristic dark green eggs, about 10 of which constitute the usual clutch.

The kiwi, or apteryx, is the smallest of the ratite birds. Several species are known, all of which inhabit New Zealand, where they are now becoming rare. The species on exhibition in the bird house is *Apteryx mantelli*, confined to North Island. The plumage is hair-like. Kiwis are shy, retiring birds; they feed principally upon worms, for which they probe the earth with the long bill.

THE STORKS AND THEIR RELATIVES

This group (Ciconiiformes) of water birds includes, among other families, the pelicans, cormorants, snakebirds, herons, storks, ibises, and flamingoes. Most of the species are essentially aquatic and some are among the most expert of swimmers. Other kinds are primarily waders, with long legs and with the feet imperfectly webbed. There is likewise great variation in the power of flight and among the diverse species are found some of the swiftest and most graceful as well as the most sluggish of water birds awing.

PELICANS AND CORMORANTS

The members of the section of ciconiid birds which includes the pelicans, cormorants, and darters are distinguished from the storks and herons by their very short legs and the completely webbed feet; even the hind toe, which is in reality turned sharply inward, is connected by a web.

The American white pelicans (*Pelecanus erythrorhynchos*) are graceful birds on the wing or in the water and very clumsy ashore. In the breeding season a curious horny knob appears on the bill of the adult bird. These pelicans are common in the interior of western North America; the specimens inhabiting the "pelican pond" came from Wyoming. The brown pelican of the Southern States (*P. occidentalis*) and several exotic species are exhibited in summer in the big flight cage.

Pelicans are fascinating birds to watch and frequently reward the observer with some queer antics. On one occasion the flock of American white pelicans in the park was seen to form a circle in the water, all the birds intent toward the center, with bills frequently submerged. Suddenly the cause of the commotion was apparent, for

one of them seized a water snake about $2\frac{1}{2}$ feet long and tossed it some distance in the air. This act was quickly repeated a number of times by different birds until one of the pelicans swallowed the unfortunate snake. He attempted to keep his prey down by holding his bill close to the body, but his efforts were unavailing, for the snake wriggled up into the gular pouch and eventually forced his way out of the pelican's mouth and escaped. One of the pelicans once swallowed a black-bellied tree duck and retained the bird in his stomach for 60 hours, but finally disgorged it, only partially digested. Various unusual objects have been swallowed at different times by the pelicans; a sharp bamboo cutting about 6 inches long worked its way out of one bird's stomach and was removed after it had pierced the lower body. This pelican did not seem to suffer in the least from his experience and did not miss a meal. An American white pelican received at the park October 7, 1897, is still living in good health.

Numbers of cormorants (*Phalacrocorax auritus floridanus*) regularly breed in the flight cage, constructing their nests of sticks in the branches of the larger trees within the inclosure. That these birds are well satisfied with their home is proved by the fact that one which escaped and remained away for more than a day returned to the cage; the keeper found him near the door waiting to be let in.

HERONS AND STORKS

Several species of stork-like birds are regularly kept in the big flight cage; some hardy kinds like the black-crowned night herons (*Nycticorax nycticorax naevius*) and the great blue herons (*Ardea herodias*) remain out throughout the year. The night herons breed within the inclosure, and wild birds of the same species build their nests on top of the great cage and in the neighboring tree tops. More delicate species, including the snowy egret (*Egretta candidissima*), nearly exterminated in the Southern States for the millinery trade, the curious boatbill (*Cochlearius cochlearius*), and the beautiful scarlet ibis (*Guara rubra*), all from South America, have permanent quarters in the bird house. The roseate spoonbills (*Ajaia ajaja*) and several species of ibis summer in the open flight cage, but are kept in the bird house in winter.

The storks, typical members of this group of birds, are represented by several species, including an American form, the wood ibis (*Mycteria americana*) which is regularly found in the Southern States and in tropical America. The marabou stork, or adjutant (*Leptoptilos dubius*) is a striking bird with a naked head and neck, a powerful beak, and a white ruff above his shoulders; he is native to the Indian region. The common stork of Europe (*Ciconia ciconia*) and the black stork (*C. nigra*) are both shown. The latter

is an especially attractive species; shiny black in color, with a white breast and belly, and bright red bill and feet. The white storks have several times nested in the great flight cage.

THE FLAMINGOES

These pinkish birds with long legs and neck and angular beak are in many ways connecting links between the storklike birds and the ducks and geese. Several species are found in parts of tropical America and one formerly occurred in Florida, but the species living in the pelican pond is one of the Old World forms, the European flamingo (*Phaenicopterus roseus*). The birds thrive in this place, but during the colder months when confined in the bird house they are difficult to keep in good condition.

DUCKS, GEESE, AND SWANS

The most picturesque and ornamental of all the birds for outdoor exhibition in zoological gardens are the true water-fowl, the game birds known as ducks, geese, and swans. Numerous showy species have been domesticated or brought to a condition of semidomestication and other more unusual species are successfully kept in captivity under proper conditions. The group is cosmopolitan in distribution, and no less than 67 species and subspecies are known from North America north of the Mexican border. The order (Anseriformes) includes besides the typical family of waterfowl a small group of South American birds known as the screamers.

THE NORTH AMERICAN WATERFOWL LAKE

In the southeastern side of the park advantage has been taken of the natural topography to reproduce in a measure one of the waterfowl breeding lakes formerly so numerous in the Northern States. For educational purposes, the birds kept in this lake have been restricted to those species known to occur in North America, as enumerated in the check list of North American birds. Bordering the lake on three sides is a tract of land sufficient in size to furnish retired nesting places for the birds and suitable for their varied requirements—woods, thickets, open brushy areas, cane, and marshes. The whole tract is inclosed by a vermin-proof fence so that the birds may nest and rear their young in safety. It is the intention to show in this lake as many of the 67 species of North American ducks, geese, and swans as possible, and a good beginning has been made in collecting the birds. At the present time no less than 250 waterfowl are on exhibition in the North American lake, including 33 different species.

EXOTIC WATERFOWL

Numerous interesting and beautiful exotic waterfowl are on exhibition in the pelican pond, in the flight cage, and in special inclosures in suitable places throughout the park. Specimens of the graceful mute swan (*Cygnus gibbus*) enjoy the freedom of Rock Creek and nest along its banks. The strange black swan of Australia (*Chenopsis atrata*), the pied goose (*Anseranas semipalmata*) from the same region, the bar-head goose (*Anser indicus*) from India, the rosy-billed pochard (*Metopiana peposaca*) and the upland goose (*Chloëphaga leucoptera*) of South America are examples of the variety shown. A large flock of the most strikingly ornamental and curiously colored mandarin duck (*Dendronessa galericulata*) is maintained. This species is native to eastern Asia, particularly China and Japan.

Of particular interest among the waterfowl is the Hawaiian goose (*Nesochen sandvicensis*). The park is very fortunate in possessing specimens of this fine goose, which is now all but exterminated. The Hawaiian goose is confined to the island of Hawaii, where it formerly inhabited the crater meadows and, during the breeding season, the lava beds near sea level.

BIRDS OF PREY

The hawks, eagles, and vultures, commonly known as birds of prey, form a natural and well-defined order, the Falconiformes. The group contains the largest of flying birds and most of the species are of good size, but some of the falcons are barely larger than sparrows. The owls were formerly placed in this order, but are now known to be nearer in structural characters to the goatsucker family, a widely different group represented in the United States by the whippoorwill and related birds.

THE EAGLES' CAGE

The large open flight cage near the bird house is devoted to such larger members of this group as will endure our winter climate and live peacefully together. Here may be seen magnificent specimens of our national bird, the bald eagle (*Haliaeetus leucocephalus*), showing the transition plumages from the younger blackish specimens to the fully plumaged adult with white head and tail. The largest specimens of this bird come from Alaska and the Northwest, while the eagles from Florida and other Southern States are very inferior in size. Another eagle found in the United States, but with an extensive Old World distribution as well, is the golden eagle (*Aquila chrysaëtos*). It is a fine species, distinguished from the bald eagle in any plumage by the feathered legs.

A number of exotic eagles and vultures, some of which are of great size, share this cage with the American eagles. The lammergeier (*Gypaëtus barbatus*), or bearded vulture, is a large species connecting in many features the eagles with the vultures. It is a native of the higher mountains of Europe, north Africa, and Asia, and many tales of its boldness and strength have been told. The griffon vulture (*Gyps fulvus*) and the cinereous vulture (*Aegypius monachus*) are two conspicuous Old World species kept in this cage. During the early spring months the griffon vultures become very savage and sometimes attack their cage mates—even the eagles are made to suffer on these occasions unless the griffons are removed from the cage. Two specimens of the handsome wedge-tailed eagle (*Uroaëtus audax*) of Australia are kept in this cage. Because it eats the poisoned meat-baits thrown out by the ranchers to destroy the wild dogs, this characteristic Australian bird is said to be rapidly diminishing in numbers, and is in danger of extermination.

INTERESTING RAPTORES IN THE BIRD HOUSE

Several interesting specimens of eagles and vultures are to be seen in the bird house. The secretary bird (*Sagittarius serpentarius*) is a peculiar African type with long legs, tail, and wings, and a crest of elongated feathers at the back of the head. In appearance it is very cranelike, and is expert in the killing of snakes, lizards, and small mammals.

The harpy eagle (*Thrasaëtos harpyia*) is a tropical American species famous for its strength and spectacular appearance. It is a large species with a long, barred tail, a fine crest, an enormous beak, and powerful feet. It is said to kill fawns, monkeys, and peccaries. The park is proud of its record in having kept a fine specimen of this bird for 18 years.

The caracara (*Polyborus cheriway*) or "carriion hawk" is common in parts of tropical America and ranges northward to Florida. Other related species are known from South America.

Various North American and exotic hawks are also on exhibition. The red-tailed hawk (*Buteo borealis*) is one of the common species of the United States which, with other kinds, is much persecuted as a "chicken hawk." As a matter of fact this bird rarely kills chickens and is an industrious destroyer of noxious rodents. One of the smaller species shown is the sparrow hawk (*Falco sparverius*), a pretty and valuable species which eats many grasshoppers, mice, and other pests of the farmer. Cooper's hawk (*Accipiter cooperi*), another of the smaller species of America, is more destructive to poultry and birds.



OSTRICHES



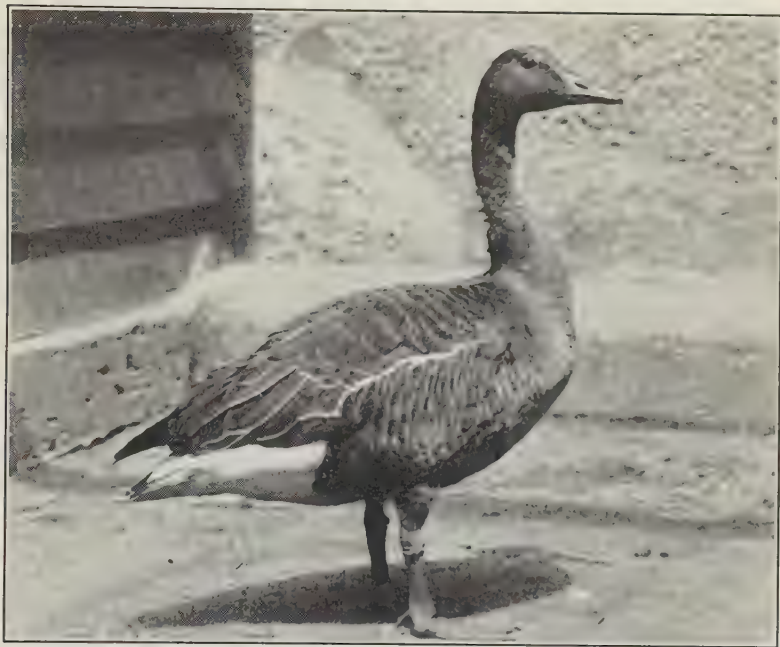
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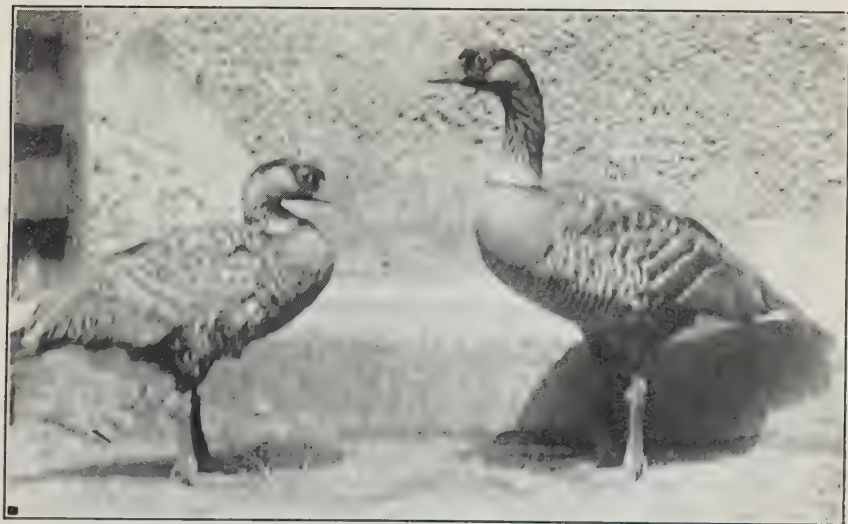
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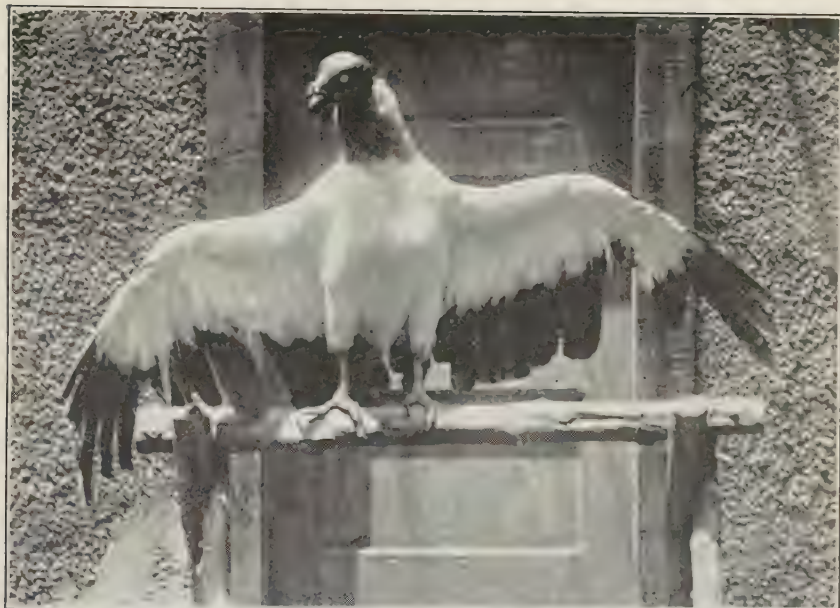
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SECRETARY BIRD



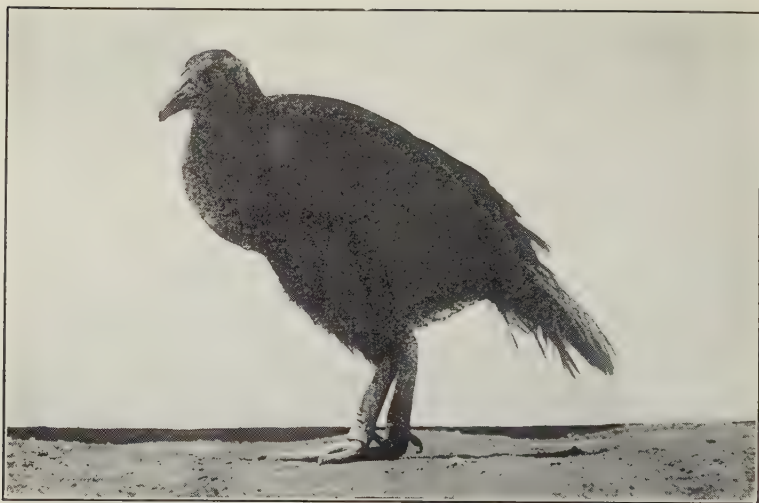
AFRICAN BLACK VULTURE



KING VULTURE



RAZOR-BILLED CURASSOW



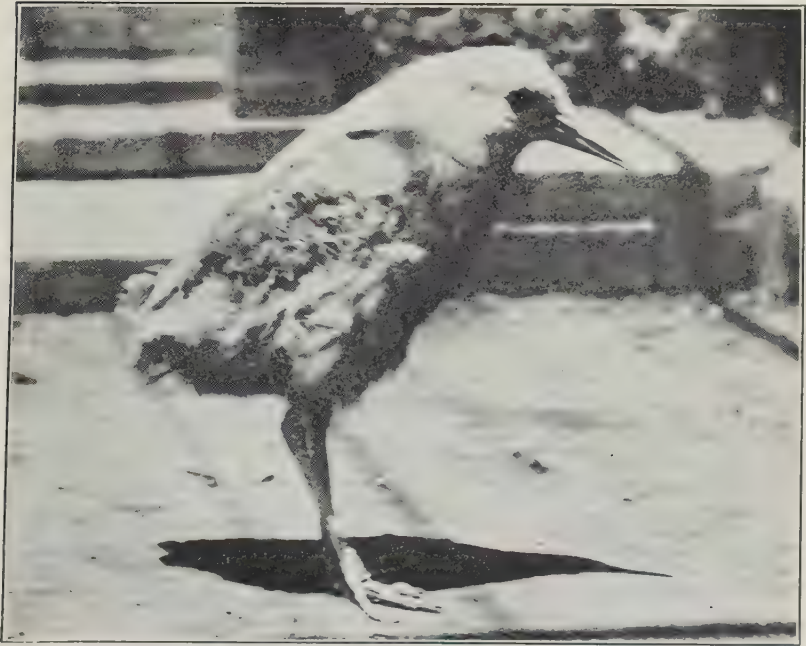
WEKA



SARUS CRANE



WHITE-BACKED TRUMPETER



KAGU



SULPHUR-CRESTED COCKATOO



TOUCAN

AMERICAN VULTURES

A group of raptorial birds peculiar to America includes our common turkey vulture or "buzzard," the carrion crow, and the condors. There is little necessity for showing specimens of the turkey vulture (*Cathartes aura*) in cages, since many wild birds of this species make the park their permanent home. The retired wooded slopes bordering the Zoo offer ideal congregating and roosting places for all the "buzzards" of the surrounding country. The birds are encouraged to remain here as an added attraction to the park, and many visitors from Northern States to whom the "buzzard" is an unfamiliar sight are delighted to see them at such close quarters and to watch their graceful flight.

The California condor (*Gymnogyps californianus*) formerly ranged northward along the Pacific coast to the Columbia River and was an abundant bird in southern California. It is now rarely seen, great numbers having been poisoned by the ranchers in efforts to exterminate the carnivorous animals. A few linger in parts of southern California and in the San Pedro Martir Mountains of Lower California, Mexico. It is deplorable that so fine a member of our avifauna should disappear, but the same fate is in store for other less notable species—even the exceedingly beneficial turkey vulture, after long years of protection, is now under the ban of mistaken legislation and is becoming greatly reduced in numbers in many of our Southern States. Three splendid specimens of the California condor are shown in an outside cage west of lion-house hill.

Another striking bird of this group is the king vulture (*Sarcophaga papia*), also of South America. It is a beautifully colored species which has a habit of strutting or dancing with the body held rigidly erect, the wings partially spread, and the head thrown forward against the breast.

GALLINACEOUS BIRDS

This order includes all of the true "fowls," domestic poultry, and the various species of pheasants, quail, and grouse. It is a group of birds of special interest to the sportsman, since almost all of the so-called upland game birds are members of the order. Many species of gallinaceous birds are of great beauty and are kept purely for show purposes, while others are easily reared in sufficient numbers to stock depleted covers and provide recreation for lovers of outdoor sports. Game keepers have paid much attention in late years to breeding the more hardy and easily kept species and are now turn-

ing their attention to experimental work in the hatching and rearing of the more difficult native varieties.

Peafowl (*Pavo cristatus*) and bobwhite quail (*Colinus virginianus*) roam at large and nest within the borders of the park, but until a suitable pheasantry can be established the exhibition of gallinaceous birds must necessarily be restricted to such species as are easily kept under ordinary conditions. A few showy pheasants and several American forms of quail or partridge are kept in the bird house.

The curassows are fine, large gallinaceous birds found from Mexico to South America. There are a number of species, two of which are shown—the razor-billed (*Mitu mitu*) and Daubenton's curassow (*Crax daubentoni*). Unlike most of the forms of this group of birds, the curassows are largely arboreal in habit and nest in trees. The feathers of the back and rump are always soft and downy, unlike those of the other gallinaceous game birds.

Closely related are the penelopes and guans, of which the chachalaca (*Ortalis vetula*), ranging north into Texas, is an example. Several South American forms are on exhibition, the finest of which is the Bolivian penelope (*Penelope boliviana*). These large gallinaceous birds are very attractive pets and become most tame and confiding.

CRANES AND THEIR ALLIES

This group (Gruiformes) includes the cranes, rails, cariamas, and bustards, as well as some lesser known forms. It has a wide distribution, and as its members are frequently classed as "game birds," it has a great popular interest. The cranes comprise some of the most showy of zoological park avian exhibits and are now much sought by private collectors of living birds. The remaining families within the order are less often seen in zoological gardens, but are, nevertheless, all birds of more than ordinary interest to the ornithologist.

One of the finest species, the great whooping crane (*Grus americana*) is bordering upon extinction. It bred formerly from northern Mackenzie south to Illinois and Iowa and occurred commonly in migrations through the Central and Southern States. It is a splendid bird; white, with black primaries and primary coverts. Naturally a wild and wary creature, it rapidly became scarce after its breeding grounds were settled by man, and it is now virtually impossible to obtain specimens.

The sand-hill crane (*Grus mexicana*) is another American species, still common in parts of Florida and in the Western States. Like the white crane, it is a shy bird and difficult to secure, and the rapid settlement of its range has naturally greatly reduced its numbers.

In parts of the upper Mississippi Valley, where it formerly bred but now occurs only in migration, it is a bird of the prairies and corn-fields, where its habits are much the same as those of the Canada goose. Small flocks flying low over the prairies, to and from the feeding grounds, are easily mistaken for geese, but when the birds are migrating, in great circles high in the air, there is no cause for misidentification. At reasonable range, flying cranes are readily distinguished from geese by the long legs, extending backward; and may be instantly known from the blue heron (often erroneously called blue crane) by the long neck, which is held extended forward and never folded back as with the herons.

The little brown crane (*Grus canadensis*), much like the sand-hill crane but smaller, is still common in the West. It breeds in Alaska and northern Canada and winters in Texas, California, and Mexico.

A number of exotic cranes, some of striking appearance, are regularly kept in the park. Of the genus *Grus* a number of Asiatic species are shown, including the large sarus crane (*Grus collaris*), the white-necked crane (*G. leucauchen*) so often pictured in Japanese drawings; the Indian white crane (*G. leucogeranus*); and Lilford's crane (*G. lilfordi*), which represents the common European crane in eastern Siberia. A fine Australian species (*G. rubicunda*) is often called the "native companion."

The demoiselle crane (*Anthropoides virgo*) of southern Europe and Asia and northern Africa is a pretty little species with white ear tufts; and the crowned crane of Africa (*Balearica pavonina*) is a still more handsome form supporting an erect occipital tuft which is decidedly showy.

Specimens of the American coot (*Fulica americana*), representing the rail family, may be seen in the North American waterfowl lake. This bird, often called the "mud hen," or "crow duck," has a wide distribution in North America. It breeds from central Canadian Provinces south to Texas, Tennessee, and New Jersey; and winters from the Central States to northern South America. In many places the coot is classed as a game bird, and properly cooked it provides a very palatable food. Several exotic relatives are always on exhibition.

An interesting flightless rail from New Zealand, known as the weka, differs greatly from our common members of the family in habits, as it is a bird of the forest and scrub rather than of wet marshes or lakes. Although the wekas have imperfectly developed wings, and are incapable of flight, they are expert climbers, and the inclosure in which they are kept must be covered completely. They are of the size of a well-grown pullet and are quarrelsome and mischievous, even among others of their own kind. Three species

(*Ocydromus australis*, *O. brachypterus*, and *O. earli*), all from South Island, are on exhibition. They were received as a gift from the New Zealand Government.

The white-backed trumpeter (*Psophia leucoptera*) represents a group of South American birds related to the cranes and rails. The trumpeters are forest birds and are sometimes found in considerable flocks. They are easily tamed and are often kept by the natives to protect domestic poultry, much as our farmers keep the guinea fowl for the same purpose. The loud call must be particularly impressive when heard in a dark jungle.

Another member of the crane assemblage is the kagu (*Rhynochetos jubatus*), a rare bird found only on the island of New Caledonia, east of Australia. It represents an ancient type, with no existing near relatives. The kagu is about the size and general form of a night heron. Several specimens of this unusual bird are on exhibition.

SHORE BIRDS, GULLS, AND PIGEONS

In most modern systems for the classification of birds, the snipes and plovers, gulls and terns, auks, and pigeons are grouped together in a single order (Charadriiformes), which takes its name from the typical family, the plovers (Charadriidæ). A few species of "shore birds," as the plovers and snipes are usually called, and some gulls, are regularly kept on exhibition; but the chief interest in the order, so far as zoological gardens are concerned, is concentrated on the sub-order Columbæ, the pigeons and doves.

The shore birds are difficult to keep without the specially prepared quarters which it is hoped the park can sometime arrange; but from the fact that a specimen of the ruff (*Philomachus pugnax*) was on exhibition in the bird house for over 10 years, the outlook seems encouraging for success with other species of this interesting family. Avocets, stilts, plovers, curlews, and many of the larger snipes should be as easily kept as the ruff. Two species of lapwings are now shown.

Certain members of the gull family are to be seen in the big flight cage. These include the large herring gull (*Larus argentatus*), a species common to the northern parts of both Europe and America which has nested here; the more tropical laughing gull (*L. atricilla*), a smaller, more graceful species sometimes called the "black-headed gull"; the beautiful little silver gull (*L. novæhollandiæ*) of Australia; and the large Pacific gull (*Gabianus pacificus*). The finest of all the American species, the great black-backed gull (*Larus marinus*), is so destructive to smaller birds in the same inclosure that the specimens in the park must be exhibited only with large geese, swans, and pelicans, or kept in separate yards.

PIGEONS

Numerous species of doves and pigeons are kept in the larger cages of the bird house. These include representatives of the group from many parts of the world, and form a very attractive exhibit. The soft colors and beautiful forms of the various species, as well as their pleasing notes, make them great favorites with all. Among the larger and more showy forms are the great, plump wonga-wonga (*Leucosarcia picata*) of Australia, curiously marked with white forehead and pectoral bands; the European wood pigeon (*Columbia palumbus*); the handsome bronze-wing (*Phaps chalcoptera*); and the green doves (*Chalcophaps*) of India and New Guinea.

Opposed to these larger species are some groups of small doves, found in both the Old World and in the warmer parts of America which are particularly noticeable on account of their diminutive size. These include the Australian and East Indian members of the genus *Geopelia* known as the peaceful and zebra doves, and the little ground doves (*Chaemepelia*) and Inca doves (*Scardafella*) of the southern United States and tropical America.

The Australian crested pigeon (*Ocyphaps lophotes*) has a long black crest which it frequently erects, at the same time elevating the tail until the two almost meet.

The New Guinea fruit pigeon (*Ptilopus superbus*) and the Marquesas Island dove (*Gallicolumba rubescens*) are among the rarer species on exhibition. The latter was first made known in 1814, but was never rediscovered until 1922.

The gigantic crowned pigeons, or gouras, are the most spectacular of all the group. They are found only in New Guinea and on some of the neighboring islands, and are from 25 to nearly 34 inches in length. They are beautifully colored and are further ornamented by large fan-shaped crests. The species on exhibition, the Victoria crowned pigeon (*Goura victoria*), inhabits the islands of Jobi and Mysori.

CUCKOOS AND PARROTS

The cuckoos and plantain eaters and the great tribe of parrots, macaws, and cockatoos form the order Cuculiformes. The first group is poorly represented in the average zoological park collection, but the parrots and their kindred usually form not a small proportion of any exhibition, and certain species are almost as familiar to the average person as is the common canary.

Over 500 species of parrots and their allies are recognized and these are distributed throughout the tropical countries of both the Old World and America. Parrots are not confined to the Tropics, however, since Australia and New Zealand support many species,

and in North America the Carolina parakeet formerly ranged northward to Wisconsin. Australia, New Guinea, and South America are especially rich in members of the parrot tribe.

There is always a good representation of these birds in the National Zoological Park. With the exception of a few hardy species, all are exhibited in the bird house. In one outdoor cage may be seen several species of cockatoos, including the bare-eyed (*Kakatoe gymnopsis*), the beautiful roseate (*K. roseicapilla*), and the sulphur-crested (*K. galerita*), and the red-and-yellow-and-blue macaw (*Ara macao*). The cockatoos are native to the Australian region and the Philippine Islands. They are handsome birds, but their shrill shrieks are unpleasant to hear. Several other species are shown in the bird house, including the white (*K. alba*), the great red-crested (*K. moluccensis*), and the beautiful rosy-tinted Leadbeater's cockatoo (*K. leadbeateri*).

The macaws are tropical American birds, mostly of large size and gaudy plumage. In addition to those in the outside cage, other species, including the yellow-and-blue (*Ara ararauna*), the Mexican green (*A. mexicana*), the severe (*A. severa*), and Cassin's (*A. auricollis*), may be seen in the bird house. The latter is a very rare species, our specimen of which was collected in 1922 by the Mulford Biological Explorations of the Amazon Basin, in Bolivia. A diminutive species is Hahn's macaw (*Diopsittaca hahni*).

The thick-billed parrot (*Rhynchopsitta pachyrhyncha*) is the only member of the parrot group, excepting the almost extinct Carolina parakeet, known to occur in the United States. At intervals a number of years apart, flights of these birds arrive in the mountains of southern Arizona, coming out of Mexico.

A group of parrots known as the Amazons occur in tropical America. There are about 50 species known, the greater part of which are green with red markings in some part of the plumage. They are common cage species and include some of the best of "talkers." Unlike the macaws, all have short tails. The collection now contains 14 species of this group.

An African species which is considered to be fully equal to some of the Amazons as a talker is the gray parrot (*Psittacus erithacus*). It is an ashy gray in color, with black wing feathers and red tail. A very attractive group of parrots, many species of which are popular as cage birds, is the group known as the parakeets. These are all small birds, some of them actually diminutive. One of the commonest forms kept as a pet is the shell parakeet, or Australian grass parakeet (*Melopsittacus undulatus*). This species breeds in captivity, nesting in a small box placed within its inclosure. In a wild state it is said to flock by thousands and spends a considerable portion of the time on the ground, feeding upon the seeds of grasses.

The love bird (*Agapornis pullaria*) belongs to an African section of the parakeet tribe and is also popular as a cage pet. The park is fortunate in the possession of a splendid specimen of the black-tailed parakeet (*Polytelis melanura*), a handsome Australian species now very rare.

Small American species on exhibition include the white-eyed paroquet (*Aratinga leucophthalmus*); a number of species of the genera *Brotogetis* and *Tirica*, including the favorite Tovi; *Eupsittula*, including the golden-crowned, Petz's, and Weddell's paroquets, and the peculiar short-tailed parrot (*Graydidascalus brachyurus*), a species rare in captivity. One of the most attractive exhibits is a cage containing a number of specimens of the curiously marked and very entertaining caiques (*Pionites xanthomeria*) from the Rio Beni, Bolivia. These are rarely obtained.

The Australian region is inhabited by a group of beautiful parrots known as lorries, several species of which are usually exhibited.

One of the most remarkable of all the parrot tribe is the kea, or mountain parrot (*Nestor notabilis*), confined to the South Island of New Zealand. This bird was formerly abundant in the mountainous parts of this region, but owing to its acquired habit of killing sheep has been so reduced in numbers that specimens are now very difficult to obtain. The flock exhibited in an outdoor aviary near the bird house was received as a gift from the New Zealand Government. It was more than 10 years after the kea was first discovered in 1856 before it was suspected that this bird had developed the habit of killing sheep, and there was considerable doubt expressed for a number of years. It has been definitely proven since that although all the individuals of the species have not acquired this remarkable change of habit, many of the birds do really kill full-grown sheep. The kea lights on the rump of the sheep, clinging to the wool, and drives his sharp beak into the unfortunate animal's back. The fat, flesh, and intestines of the sheep are eaten by the birds, who frequently go in large flocks.

KINGFISHERS, HORNBILLS, AND OWLS

The kingfishers, hornbills, and owls are members of an order of birds (Coraciiformes) which includes other seemingly unrelated families—as the woodpeckers, hummingbirds, goatsuckers, and swifts. It is what Coues calls a "miscellaneous assortment, grouped together more because they differ from other birds in one way or another, than on account of their resemblance to one another." Recent anatomical studies have, however, shown the actual relationships in many cases.

Passing through the bird house one may be suddenly startled by a loud, rapidly executed, and prolonged cackling laugh. This is from the throat of the giant kingfisher, or laughing jackass (*Dacelo gigas*), an Australian bird related to our common American kingfisher, but of a decidedly greater size. Near by are representatives of the hornbill family, found in the forests of Africa, India, and many of the eastern islands, where they are hunted for food by the natives of some districts. In many regions, however, these grotesque birds are regarded with considerable superstition and are rarely molested. These remarkable birds have a most curious nesting habit. A large cavity in a tree is selected for the nest and the female hornbill is confined therein by a plaster wall, both birds apparently taking part in the process of masonry, which makes her a prisoner until the young are hatched. During the incubation period she is fed by the male through a small hole left in the wall, but is said to come forth in a much emaciated and dung-bespattered condition.

In an inclosure near the big flight cage are some 15 specimens of the great horned owl (*Bubo virginianus*), one of the largest of the American birds of prey, as well as one of the most destructive to smaller birds. Other owls, including the highly beneficial species known as the screech owl (*Otus asio*), the barred owl (*Strix varia*), and the barn owl (*Tyto perlata pratincola*) are also shown in large cages. One of the handsomest of all owls is the great white, or snowy owl (*Nyctea nyctea*). This is a diurnal species of the far North, where it inhabits the open country of both continents. It is expert in catching fish and feeds also on birds and mammals. The snowy owl spends much of its time on the ground. During severe winters numbers of snowy owls visit the northern United States.

The toucans, large and sometimes brilliantly colored birds of tropical America, are remarkable for their large bills. These are not at all unwieldy, however, since they are very light in structure. Toucans feed chiefly upon fruits, but also eat insects and the eggs and young of other birds. Numerous species are known, some of the most showy of which often reach the bird dealers, since toucans are commonly taken by the natives as pets.

THE PERCHING BIRDS

More than half of all the species of birds known in the world belong to the order Passeriformes, frequently called the "perching birds," and typified by the sparrows. There are numerous families and the vast majority of species are small or medium sized birds; the largest North American species are the crow and raven.

In some of the larger cages of the bird house numerous species of this order of birds are shown. There will be seen many of the more familiar native species as well as rare and beautiful exotics. In near-by cages are some of the larger representatives of the order, including ravens, crows, magpies, and starlings from various corners of the earth. Among the most attractive of the smaller birds are the numerous species of the finch or sparrow family, of which the common canary (*Serinus canarius*) is a familiar member.

The weaver birds, native to Australia, India, and Africa, attract a great deal of attention; this is especially true of the species known as the paradise weaver (*Steganura paradisea*), which grows tail feathers of great length in the breeding season.

The satin bower-bird (*Ptilonorhynchus violaceus*) and the Australian catbird (*Ailurædus viridis*) are interesting forms belonging to the family of birds-of-paradise, which is not distantly related to the crows. One of the most showy of all the perching birds exhibited in the park is the cock-of-the-rock (*Rupicola rupicola*), a bright orange species of tropical South America.

REPTILES

Reptiles (class Reptilia), as distinguished from mammals and birds, are "cold blooded." The temperature of the animal is greatly influenced or even regulated by that of the surrounding air, or of the water in which it lives.

Three orders of reptiles are represented in the park collections. These are the turtles and tortoises (Testudinata), alligators and crocodiles (Loricata), and the lizards and snakes (Squamata). One of the urgent requirements of the National Zoological Park is a suitable reptile house, where larger collections of these interesting creatures may be exhibited. At present the reptiles are kept in quarters in the lion house.

TURTLES

Those turtles living entirely on land are often arbitrarily distinguished from the aquatic species (true turtles) and the semiaquatic forms (terrapins) under the name tortoise. Some of the tortoises are small in size, like our common box turtle of the Eastern States; while others, particularly some of the island species, grow to an immense size and are supposed to live to a greater age than any other animals. These giant tortoises are now known only from a few islands in the Indian and Pacific Oceans, on some of which they were excessively abundant up to comparatively recent years. Visiting ships have now so greatly reduced their numbers that on most of the islands they are completely or almost exterminated. On certain

of the Galapagos Islands, some 500 miles off the coast of Ecuador, giant tortoises were found in great numbers within the last century, and on certain of the islands were fairly common less than 25 years ago. In addition to the thousands carried away by vessels as food for the crews, great numbers have been killed for the oil alone.

A number of species of giant tortoises have been described from the Galapagos, and it is believed that most of the islands of the archipelago have developed separate forms; and on at least one island two distinct species were found, separated by a natural barrier. The food of these curious creatures is chiefly grass, although at certain seasons a great quantity of cactus is eaten. Mr. Edmund Heller, who visited the Galapagos Islands in 1898 and 1899, collected one specimen which had the whole palate and pharynx bristling with cactus spines, and noted that the tortoises eagerly devoured the stems and fruit of the cactus quite unmindful of the spines and apparently without suffering. Heller states that the tortoises are quite active, and though slow are so persistent in their journeys that they cover several miles a day.

Specimens of two species of Galapagos tortoises were obtained for the park collection from the material collected by the Rothschild expedition to the islands in 1897. The Albemarle Island tortoise (*Testudo vicina*) is perhaps the largest living tortoise, and specimens have been known which were over 4 feet in length and probably weighed nearly 400 pounds. The Duncan Island tortoise (*T. ephippium*) is somewhat smaller. A third species of the giant Galapagos Island tortoises from Indefatigable Island (*T. porteri*) was more recently received through the interest of Dr. Frederic W. Goding, consul general at Guayaquil, Ecuador. A smaller related tortoise (*T. denticulata*) is from the continent of South America.

In the pine barrens of the Southern States, a comparatively large tortoise, curious for its burrowing habits, is known as the gopher. This species (*Gopherus polyphemus*) grows to a length of 15 inches and a specimen almost of that size from peninsular Florida is on exhibition. Like the giant tortoises, this species is herbivorous and is particularly fond of fruits of various kinds. Related species shown are found in the arid regions of the Southwest and other parts of the world.

The common eastern tortoise or box turtle (*Terrapene carolina*) is found wild within the park. It is a smaller species than the gopher, and the plastron or lower shell is so hinged as to permit the animal when alarmed to close itself completely within its armor.

Specimens of the common native snapping turtle are sometimes captured within the park. One of these reptiles caused considerable damage among the waterfowl in the beaver pond before he was

finally caught by the keepers. The large specimen of a related, but much rarer, species from Central America (*Chelydra rossignoni*) was collected by Dr. Wm. M. Mann in Honduras.

ALLIGATORS

The common alligator of the Southern States (*Alligator mississippiensis*) is well known to a large proportion of our people; thousands of the young have been carried by tourists from Florida to all parts of the United States. The species formerly was abundant in fresh-water streams and swamps throughout its range—north to North Carolina and west through the humid portions of Texas. In all of the more accessible and settled portions this reptile has suffered greatly from hunters, professional and amateur; and in most parts of its former range it is now a rare thing to see an alligator of any size. In some of the streams and swamps of the wilder places within the Gulf States, however, it is still possible to find alligators from 6 to 8 or 9 feet in length; but the 10 to 16 foot reptiles are practically gone.

The nest of the alligator has frequently been described to me by old residents in Florida as resembling the nests made by the wild "razorback" hogs of that country. It is a great mound of muck, grass, moss, and sticks; placed in a retired spot, and is said sometimes to be carefully guarded by the female. The numerous eggs are hatched by heat generated by the rotting vegetation.

THE LIZARDS

Most of the American lizards are graceful and innocent creatures and many are beautifully colored. They are as much a delight to students of reptiles as our warblers are to the ornithologists. There are, however, two large species found in the Southwest and in Mexico which are dangerous reptiles. They are known as the beaded or tuberculated lizards, are sluggish creatures inhabiting arid situations, and are the only known poisonous lizards.

The Gila monster (*Heloderma suspectum*) is known only from portions of Arizona, New Mexico, Sonora, and southern Nevada. It is a comparatively large species, growing to 20 inches or more in length. In color it is brown or blackish, marked with numerous rings and blotches of yellow or orange. The upper parts are heavily beaded or tuberculated; the tail is fat and stumpy, and the reptile presents altogether a dangerous and terrifying appearance. On account of his notorious disposition and because of his poisonous bite, the Gila monster is much dreaded by residents of the region in which he lives, and the several specimens on exhibition attract great attention. The poison glands are situated on the outer side of the

lower jaw near the tip. When biting the Gila monster holds on like a bulldog so that the poison may have time to become absorbed in the wound. No specific antidote is known.

Several species of the commoner lizards of small size, native to the Southeastern States, are usually shown. The glossy blue-tailed skink (*Eumeces quinquelineatus*) is one of the most handsome of the eastern forms. It is common in pine woods, especially in the South. The rough-scaled species, known as the swift (*Sceloporus undulatus*), and the little lizard, called the "chameleon" (*Anolis carolinensis*), are both abundant in favorable localities in many parts of our Southern States. The latter species has the habit of changing color and may be at times gray, green, or its normal shade of dull brown.

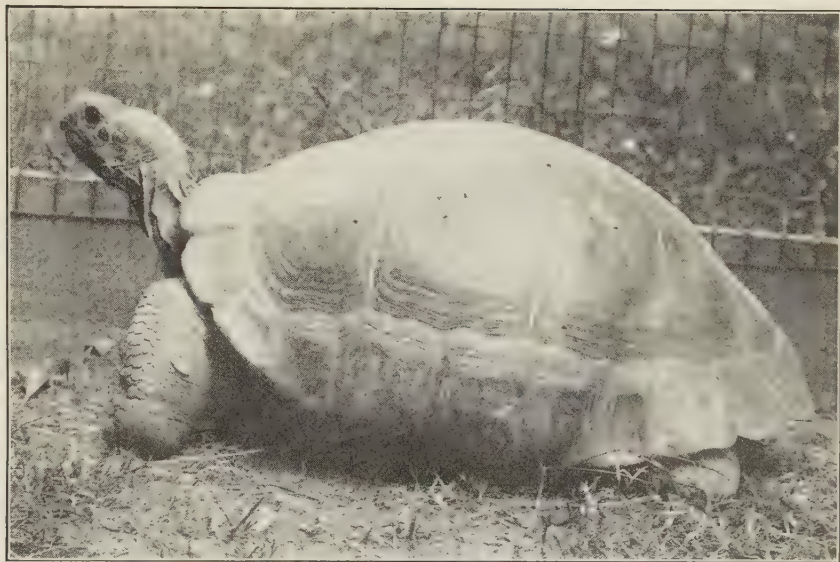
The largest known lizards are the monitors, of Africa, Asia, and Australia. They differ from other lizards in having the tongue forked like a snake. Specimens of one species, Gould's monitor (*Varanus gouldii*) from Australia may be seen in the lion house. This monitor grows to a length of nearly 6 feet and has a voracious appetite; it eats eggs, chickens, and small mammals.

SNAKES

While it is probably true that the great majority of people dislike snakes, it is also true that a collection of these reptiles attracts extraordinary attention and adds greatly to the interest in a zoological park. The larger snakes in particular are a never-ceasing source of wonder to visitors, and the more spectacular of the lesser species, like the rattlesnakes, are almost as popular an exhibit.

One of the prize specimens in the snake department of the National Zoological Park is a fine example of the anaconda (*Eunectes murinus*), or water boa, of South America. The anaconda is the largest of the American snakes and sometimes attains a length of over 20 feet. In color it is a yellowish green, marked with blackish spots. Anacondas are essentially aquatic and spend much time in the water, although they are perfectly at home in trees and are expert climbers. The numerous young are born alive. The largest specimen in the park collection has been here since August 17, 1899, and was a gift from the governor of the State of Para, Brazil.

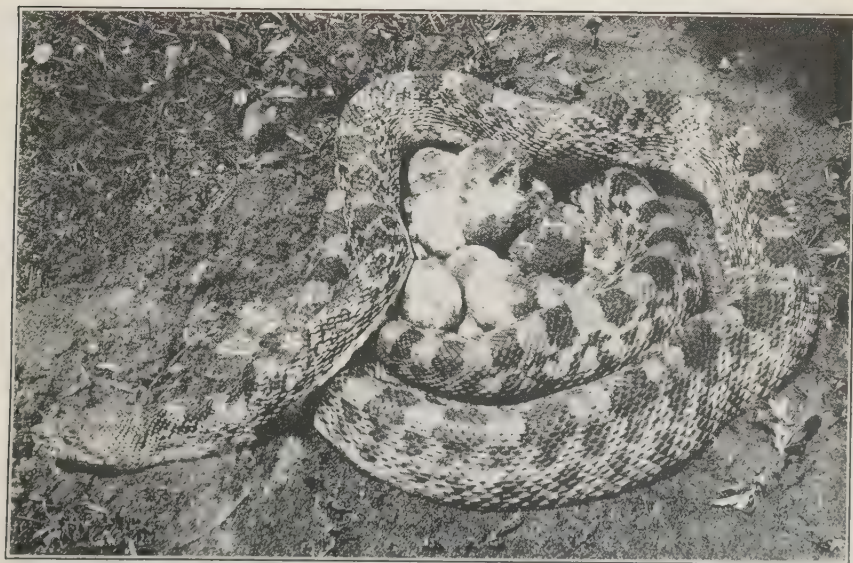
In a near-by cage are three specimens of the Indian python (*Python molurus*), native to India, the Malay Peninsula, and Java. The largest snakes known are of a related species (*P. reticulatus*); there are apparently reliable records of individuals over 30 feet in length. A specimen 25 feet long is by far the largest snake on exhibition in the National Zoological Park. This python feeds almost entirely on pigs, and sometimes, after a fast of six weeks, eats,



GIANT GALAPAGOS TORTOISE



GILA MONSTER



BULL SNAKE AND EGGS

within a few days, three young pigs weighing from 12 to 16 pounds each. The reticulated python inhabits the Malay region and the Philippines. Pythons, like the boas, are constrictors, and kill their prey by crushing. The pythons lay eggs, which are hatched by the mother who coils arounds them. The eggs number from 50 to 100. These snakes are particularly fond of climbing, and the specimens in the park collection spend much time coiled in the tops of the small trees within their inclosure. The diamond snake (*Python spilotes*), found only near the east coast of Australia, is blackish with a yellow spot in the center of each scale. It is one of the most attractive of the pythons in captivity and the specimens in the collection are much more active than is usual with large snakes. A closely related form known as the carpet snake has a much wider distribution in Australia.

The common boa, or boa constrictor (*Constrictor constrictor*) is a tropical American species of large size, but considerably smaller than the anaconda and the larger pythons. It is said rarely to reach a length of 12 feet. Several examples are shown, the largest of which came from Trinidad and is about 10 feet in length. A small specimen of the boa was found in the Washington Market packed with a bunch of bananas, and was sent to the park. This involuntary stowaway is doing nicely in his new home. Other species of boas are found in South America, the West Indies, and, strangely enough, in Madagascar.

Many species of North American snakes are usually on exhibition. Most of these are of comparatively small size, but some of them are of great beauty and others are interesting because of their terrible appearance and deadly poison. In the latter class may be mentioned the rattlesnakes, copperheads, and moccasins.

The rattlesnakes are confined to America, where many species are known, the majority of which are found in the western United States. The common or banded rattler (*Crotalus horridus*) was formerly found in many parts of the Eastern States, north into Maine, but has now disappeared from much of its former range. It sometimes grows to 5 feet or more in length. The largest rattler is the diamond back (*C. adamanteus*), which in its typical form in the Southern States reaches an immense size. Many specimens are on record from Florida which measured over 6 feet in length, and there are apparently authentic accounts of diamond backs of between 8 and 9 feet. The bite of one of these large rattlers is very likely to prove fatal.

Closely related to the rattlesnakes are the moccasin (*Agkistrodon piscivorus*) and the copperhead (*A. mokasen*). Both are poisonous species. The copperhead is one of the most dangerous snakes in the Eastern and Southern States because he holds his own in thickly settled communities; they are not uncommon about Washington,

especially along the upper Potomac above the city. Adult specimens are commonly from 24 to 30 inches long. In color, the copperhead is hazel brown, with a series of hourglass-shaped darker blotches along the back. Equally venomous is the mocassin, or cotton mouth, but he is an aquatic species and does not range so far to the north as does the copperhead.

The common water snake (*Natrix sipedon*) and the southern water snake (*N. taxispilotus*) are often mistaken for the mocassin; they are ill-tempered snakes but harmless, and on close examination may be distinguished from the mocassin and copperhead by the absence of the deep "pit" between the eye and nostril, a characteristic feature of those venomous species and the rattlesnakes.

Other harmless American snakes kept in the collection are the black snake (*Coluber constrictor*) sometimes called the "blue racer," and his near relative, the coachwhip snake (*C. flagellum*), both of which sometimes attain a length of 5 feet. Several species of the pretty little garter snakes, as well as the king snake, the pine snake, chicken snake, bull snake, gopher snake, and others are commonly shown.

THE BURROWING RODENTS OF CALIFORNIA AS AGENTS IN SOIL FORMATION¹

By JOSEPH GRINNELL

[With 3 plates]

The interrelations between vertebrate animals and their environments are exceedingly variable and far-reaching. To base any conclusion upon a contrary assumption has proven dangerous, for in specific cases such procedure has led people to expend effort and substance not only needlessly but definitely against their own best interests. An inference as to the relationships between some certain wild mammal and human affairs may at first thought look to be perfectly obvious and unquestionable. Extended examination, however, may show that many factors previously overlooked are concerned, and the comprehension of these may lead to an entirely different view.

The species and subspecies of mammals occurring in California, so far as known at the present moment, number 410; 227 of these belong to the order Rodentia. Of these, 109 are essentially burrowing rodents; that is, they have their breeding quarters, at least, beneath the surface of the ground, this circumstance entailing more or less digging, and some of them spend practically all of their time within their subterranean tunnels. These rodents of essentially burrowing habit include the following groups: The ground squirrels, with 18 species; the kangaroo mice, with 2 species; the pocket mice, with 23 species; the kangaroo rats, with 33 species; and the pocket gophers, with 33 species.

To express the above facts in more general terms: Of the total number of species of mammals living within the confines of the State, more than one-half are rodents, and of the rodents alone, just one-half are of the burrowing category; rodents that burrow constitute, by species, one-fourth of all the mammals in California. It may further be observed that rodents which burrow are more or less plentiful throughout the West. And here is another surprising fact, namely, that only one of the seven genera of mammals to which our burrowers belong is represented in the United States east of the

¹ Contribution from the Museum of Vertebrate Zoology of the University of California. Read at meeting of California Chapter of Sigma Xi, Oct. 12, 1921. Reprinted by permission from *Journal of Mammalogy*, vol. 4, No. 3, August, 1923.

Mississippi River. (The genus *Citellus* of ground squirrels furnishes the exception; two species of that genus go as far east as Indiana.) From a possibly economic bearing, with respect to digging, moles and earthworms, though ecologically not at all homologous, seem to take the place in the far eastern States that the burrowing rodents take here.

The line of demarcation, eastward of which the burrowing type of rodent begins to disappear, is, approximately, the one-hundredth meridian. In other words, there is a north and south line of transition between two major faunal regions which roughly coincides with this meridian. The limitations of the animals in question undoubtedly have to do with the physical peculiarities of the regions east and west of the one-hundredth meridian. These peculiarities involve differences in atmospheric humidity, in rainfall, and, of seeming major importance, the sharp alternation of dry and wet season which occurs to the westward. Linked up with these conditions, there is, probably, in the West a relatively greater abundance of plants with nutritious roots or thickened underground stems (corms, rootstocks).

With regard to abundance of mammals in California by individuals, I have made numerous estimates. It proves to be highly variable, all the way from zero per acre, as on parts of the floor of Death Valley, up to 120 per acre, as in certain parts of the San Diegan district. I have figured a conservative average throughout the entire State to be 20 mammals of all sorts per acre, so that the total mammal population in California, at the period of the year just before the breeding season, when the population is at its lowest ebb, is 2,000,000,000. Estimating further, on the basis of the results of trapping and of field observation in different parts of the State, I find that the population of *burrowing* rodents is at the very minimum one-half that of *all* the mammals, which would thus be in the aggregate about 1,000,000,000.

Even cursory observation suffices to establish to one's satisfaction the relative abundance of such burrowing types of mammals as ground squirrels, pocket gophers, and kangaroo rats. Along any of the railroads or highways, interminable stretches of the right of way, or of the adjacent plains or mountain slopes, show a profusion of the so-called "workings" of these animals—mounds, trails, mouths of burrows (open or closed), caved-in burrows, winter earth cores, and the like. If a person starts out on foot, he will inevitably "fall into" subterranean runways: every little while he steps through into some tunnel or cavern. The surface of the ground is seen to be nearly covered with disturbed soil showing footprints of these animals, especially if the season be the dry one. The vegetation will show abundant evidence of having been foraged upon by rodents.

Of the five types of burrowing rodents in California, the most widespread, in the aggregate the most abundant, and certainly the most effective in its equipment for turning over the soil, is the pocket gopher (*Thomomys*); and upon this type I propose chiefly to dwell. An examination of a pocket gopher shows its structure throughout to be remarkably specialized for burrowing into and through the ground. A study of its habits shows that in all probability a pocket gopher spends at least ninety-nine one-hundredths of its existence below ground. Its world is limited by the earthen walls of a cylinder. In one direction this cylinder brings safety from enemies; at the other end it brings accessibility to food. We find that the gopher is deficient relatively to other rodents with respect to eyesight. Its hearing is likewise below the average and seems to be keenest for sounds of very low rate of vibration, such as jarrings of the ground. Its sense of touch is localized not only in the nose and surrounding vibrissæ, but also at the tip of the tail. The animal moves quite as well backward in its burrow as forward: it needs to be apprised of conditions in both directions.

The body as a whole is short, thick through, with a notable massiveness anteriorly—just the opposite of the litheness of structure characteristic of, say, the squirrels. The head of a pocket gopher is larger in proportion to its body than is that of any other land mammal in California. The head is joined to the body without any obvious neck constriction, and the shoulders are broad. The bigness of the head is accounted for both by the thicker and more ridged bones of the skull and by the greater mass of the muscles attached to them. These are correlated with the structure, position, and operation of the relatively huge incisor teeth.

The mouth is a vertical slit, guarded by furry lips which are appressed so as to keep out the earth loosened by the projecting incisor teeth or pushed ahead of the animal by means of the face and forefeet. The pocket gopher is our only mammal in which the incisor teeth can not be concealed within the lips.

Comparison of the pocket gopher, as an extreme type of digger, with the California ground squirrel, which is also a digger but to a far less degree, shows some significant differences. An average adult California ground squirrel weighs 681 grams; an average adult male pocket gopher weighs 170 grams, close to one-fourth as much. But the weight of the skull of the ground squirrel is 7.8 grams, while that of the gopher is 7.2 grams, practically the same. In other words, the skull of a gopher is four times as heavy as that of a ground squirrel, total weights considered. The brain case, however, seems to have relatively about the same capacity in the two animals. The skull and teeth of the pocket gopher, together with the muscula-

ture connected with them, comprise the chief engine of digging. Its operation results in cutting away, and in part transporting, the earth, as the animal extends its underground system of passageways. But there are also supplementary digging structures. Instead of the hind feet being larger than the forefeet, as in most mammals, the reverse is the case in the pocket gopher. We find the forefeet are larger and provided with long stout curved claws; and the forearm and shoulder are heavily muscled. Through and through, the adaptations of the pocket gopher are seen to be concentrated for the digging function.

I have excavated several tunnel systems of gophers and have recorded the diameters in various portions of their courses, and the volumes of the earth removed. I will not take space to give the figures here. Suffice it to say that the ordinary runs maintain a remarkably uniform diameter and depth below the surface of the ground. The depth varies from 4 to 8 inches, depending upon the consistency of the soil—clayey and coherent, or sandy and loose. The deeper extensions of the burrows, down to a depth of 20 inches, lead to the breeding chambers where the nests are located.

As already intimated, pocket gophers appear above ground rather seldom: they do so, as a rule, only as necessary to push out surplus earth loosened in the extension of their tunnels or to forage in the near vicinity of the open burrows. While gophers are active throughout the entire 24 hours of the day, new surface workings, marked by dark damp soil, are to be found chiefly in the morning.

The typical mound is of a fan shape, the opening of the burrow from which the earth was pushed, although closed, being clearly indicated at the base of the fan. The upraised surface of the fan is marked by more or less sharply indicated concentric "moraines," each registering the terminus of an operation from the mouth of the burrow. The rim of the mound is often irregular, the earth having been pushed farther out at some points on the periphery than at others. The mouth of the burrow is plainly outlined in a perfect circle of raised earth 2 to 3 inches in diameter, but this small circle is always lower than the preponderance of the heap.

However, a great deal of the gophers' activity at the surface of the ground is not marked by the presence of mounds. Especially during the dry season, one will find at frequent intervals circular openings in the ground which have been filled with loose earth, nearly or quite to the level of the surrounding surface. Examination will show that these burrows have been used as exits from short side branches of the main tunnels. They are used for the purpose of exploring the immediately adjacent surface for food.

A gopher is loath to leave its shelter and ordinarily does not venture as far even as the length of its body from the open mouth ?

of its burrow. As an evident result of this timidity, each feeding exit is the center of a small circle, shorn of vegetation, the radius of which is less than the body length of the gopher. The haunches of the animal, when it forages, remain in contact with the orifice of the burrow, as a sort of anchor by means of which the gopher can pull itself back into safety at an instant's warning. It is well known to gardeners that a gopher will burrow underground to some near-by plant, rather than risk capture by venturing forth on the open surface. Many times gophers tunnel toward the surface beneath plants and cut off roots and even main stems, without any disturbance being evident above ground, until the plants begin to wither and die, if they do not topple over before by reason of insecurity at the base.

In digging, the earth loosened by the strong incisor teeth and stout front claws is swept back underneath the body until a considerable amount has accumulated. The animal then turns around (being able to do so apparently almost within the diameter of its own body, which is the diameter also of its burrow), and pushes the earth along the tunnel to the surface opening where it is shoved out on top of the ground or into some other part of the burrow system no longer of use. Only the fore feet, in conjunction with the broad furry face below the level of the nose, are used in moving the earth. The outside-opening, fur-lined, cheek pouches, with which the animal is provided, and which are situated at each side of the mouth, are not used to carry earth, but solely to carry clean food materials. Most of the surface openings are at the ends of side tunnels and are but a few inches in length. After excavation has proceeded a few inches beyond one surface opening, this opening is closed and a new one is made at a more convenient location—nearer the point where the earth is being removed.

As already intimated, gophers occur very widely. In fact, in California, we find them existing under the most extreme conditions of climate, though different species are represented under the different combinations of conditions. There are pocket gophers in abundance in the vicinity of Yuma, and at Eureka; at Monterey, and around Goose Lake; at Fresno, and up to the limit of plentiful plant growth, 11,500 feet, on the slopes of Mount Whitney.

I will now give some facts and information relative to the gophers in the Yosemite National Park, where Mr. Tracy Irwin Storer and myself have made definite studies of their habits.

The pocket gopher² is one of the few Sierran rodents that carry on active existence throughout the entire year. It does not hibernate.

² The species here concerned is *Thomomys monticola*.

so far as we know, even at the highest altitudes. There is good evidence of the continued work of gophers there, beneath the snow, however deep this may become. During the winter and spring in the high country, where the snow lies deep, they are led to adopt a somewhat different method in extending their tunnel systems than during the summer months. The tunnels are then made in the snow itself, a greater or less distance above, and in most of their courses more or less parallel with, the surface of the ground. These snow tunnels are usually greater in diameter than the subterranean runs, perhaps because of the loose texture of the snow as compared with that of the soil beneath; they serve the purpose of allowing the gophers to reach plants which are embedded in the snow. Many of them are used also in extending the subterranean systems. The earth from below ground is carried up and packed in the snow tunnels previously dug, thereby forming solid earth cores above the level of the ground. When the snow melts in the spring, these cores are lowered intact onto the surface of the ground, where they often remain more or less recognizable for several months, despite the winds and summer thundershowers.

The height to which the snow tunnels extend above the ground depends upon the depth of the snow-fall; but there is reason to believe that their general course is modified by the position of the above-ground vegetation encountered. After the snow has gone, in early spring, we have found portions of earth cores lying on top of flattened branches of snowbush, on fallen tree branches, on logs and rocks, indicating that the animals had pursued courses in the snow well above these objects. When active right after a light fall of snow, the gophers run their tunnels directly upon the surface of the ground, appropriating to their uses as they go the stems of grasses and other plants.

Very often the earth composing both the winter cores and the summer mounds is quite different in appearance from that of the superficial layer of the ground immediately underneath them. This makes such "workings" very conspicuous, as they are, with reference to the ground on which they lie, in the relation of a geological unconformity.

Rather than being a drawback to the interests of the pocket gopher, the snow seems to be of real benefit. Two factors are here involved. I have referred to the timidity of the animal, and this is doubtless due to the relentless pursuit of it by certain carnivorous mammals and birds with the resultant precautions necessary on the part of the gopher to keep out of sight and reach. The snow provides cover which conceals the rodent effectually from certain of its enemies. At the same time, the vertical range of accessible food sources is greatly

increased; for the gopher is able to reach plant stems and leaves enveloped in the snow mantle, many inches and even feet above the ground surface. All this is subject to confirmation through study of the winter workings uncovered at the time of the spring thaw.

Some estimates made by us while carrying on field work near Porcupine Flat, Yosemite Park, will serve to indicate the amount of work done by pocket gophers. It was found that the average amount of earth put up in the form of winter cores was, on a selected area, 1.64 pounds per square yard. Assuming that, on the average, gopher workings covered only one-tenth per cent of the land surface, there would be 3.6 tons of earth put up per square mile, or 4,132 tons over the whole park. This is for a single winter! It will be recalled that there are many square miles of either solid rock or slide rock in the park, where gophers can not work. On the other hand, in favorable localities workings occur on every square yard of surface; so that it is believed that the average of one-tenth per cent is conservative for the park as a whole. In summer the amount of material excavated is probably at least as great as that in winter—exactly how much has not yet been determined. For the year, Mr. Storer and myself feel safe in doubling the total figure just given, which, in another unit of measure, would be close to 160 carloads of 50 tons each. We estimate further that the earth to the above amount is lifted by the gophers an average distance of about 8 inches; 5,500 foot-tons of energy are expended by these little animals in Yosemite Park during a single year.

The question then presents itself as to the general effect of all this work upon the terrain at large, and further upon the vegetation and even upon the animal life of the region. I will proceed to enumerate some of these relations which seem to be borne by pocket gophers to their environment.

(1) The weathering of the substratum is hastened by the burrow systems carrying the air and the water and contained solvents to the subsoil particles and rock masses below.

(2) The subsoil is comminuted and brought to the surface where it is exposed to further, and increased rate of, weathering.

(3) The loose earth brought up and piled on the surface of the ground thereby becomes available for transportation by wind and water; rain and melted snow carry it from the slopes down to fill up glacial depressions and to make meadows of them; and when these are full, the sediment is carried on still farther by the gathering streams to contribute to the upbuilding of the great and fertile valleys beyond the foothills.

(4) Water is conserved for the reason that snow melts more slowly on porous ground than on hard-packed soil or bare rock, so

that the spring run-off is retarded and the supply to the streams below is distributed over a longer period of time; furthermore, the porous soil retains the water longer than packed ground and gives it up with corresponding slowness. Spring floods are less liable to occur and a more regular water supply is insured to the lowlands.

(5) A porous, moist soil produces a fuller vegetational cover—forest, brushland and meadow—and this again favors water conservation.

(6) The ground is rendered more fertile through the loosening of the soil as well as through the permeation of it by the tunnels themselves, thereby admitting both air and water to the roots of the plants; the mineral constituents of the soil become more readily available, and the rootlets are better able to penetrate the earth.

(7) The accumulated vegetational débris on the surface of the ground is eventually buried by the soil brought from below by the gophers, and becomes incorporated to form the humus content so favorable for the successful growth of most kinds of plants.

My readers will have been reminded by a portion of the above considerations of Darwin's classical study of the relation of earthworms to soil formation. There is undoubtedly a parallel here, the more significant in that the earthworm is a relatively rare animal in California; and what earthworms are here are of small size and of relative inconsequence in effect upon the soil. The pocket gopher is wonderfully equipped to handle the refractory young soils of the semiarid Sierran slopes, and his rôle here is, in a way, that of Darwin's earthworm in England.

The greatest of all agencies of erosion in the Sierra Nevada, the glaciers, so stressed by John Muir, have now ceased to operate, and the less obvious agencies come into prominence. The element of time granted, we are able to conceive of vast accomplishments on the part of even so humble a contributor as the pocket gopher. Gophers have been at work as gophers of modern type since Miocene times. Prof. Andrew C. Lawson thinks that the Sierran block had not begun to uptilt until early Pliocene. Gophers have probably been at work on at least the lower slopes a good share of the entire time occupied in the uplift of the Sierra Nevada.

As in the case of Darwin's earthworms, there is plentiful evidence in California as to the function of burrowing rodents in burying large objects, such as rocks and logs. Ground squirrels and pocket gophers both show an inclination toward placing their nesting chambers beneath objects that will protect them from being dug out by burrowing enemies, such as badgers and coyotes. The earth is taken out from beneath a rock or a boulder by the rodents and deposited

around the margin of the object, which thus, as the years go by, gradually disappears, as a result of the process of undermining and settling plus that of the building up of the ground roundabout. The seeker need not go far to find good cases of this kind. Mr. Joseph Dixon cites the case of a rock pile on one corner of his ranch which was half buried in 10 years. One certain rock settled 6 inches in comparison with the general land level during a period of 10 years.

Some idea of the extent of the work which gophers have accomplished through time may be gained from the following considerations. There are 33 species and subspecies of this type of burrowing rodent now in existence in California; these are all in a general way similar to one another, but each has distinctive characters which involve not only external features of color and quality of pelage but also internal structures, more especially those of the skull and teeth. These latter features, it will be observed, have to do with the digging equipment which to the gopher is of such vital importance. These characters of skull and teeth are the ones chiefly depended upon by systematic students in determining species. A remarkable thing is that no two of the 33 species occurring in California exist in any one locality. Just one kind lives in a place, to the exclusion of all other kinds. There is probably close correlation of structure with peculiarities of the terrain, as, for instance, those shown by loamy, sandy, and rocky soils.

Now the remains of gophers' skulls are found in abundance in the Rancho La Brea deposits near Los Angeles. The exact horizon in which they are found is that in which are also found the saber-toothed tiger, the ground sloth, camels, mastodons, and dire wolves. That horizon has been assigned to the Pleistocene epoch; and geologists have estimated that the time elapsed since the deposit of the materials representative of that horizon is to be computed in "tens and even hundreds of thousands of years." A remarkable thing is that a study I have just made of the gophers of Rancho La Brea, in comparison with the species existing in the same vicinity to-day, shows they are identical in every respect.³ In, say, 200,000 years there has been no modification of the same structures which at the present day vary from place to place to such an extent as to have led this group to be characterized by some zoologists as extraordinarily "plastic." The true inference here is that the processes of divergent evolution, as well as of monotypic evolution, have been exceedingly slow. This, however, is somewhat beside the issue.

If we are to grant that gophers have been in existence, carrying on their digging operations for so short a time, geologically, as 200,000

³ The species and subspecies is *Thomomys bottae pallascens*.

years, even then the total amount of turnover of the ground has been enormous. At the rate determined on one tract of land to be one-tenth of an inch per year, it would in that period of time have amounted to 1,700 feet. This is equivalent to 3,400 plowings to a depth of 6 inches.

Computations of this sort may be carried on endlessly, and it is rather good fun to do so for a while; but beyond certain limits, they are not particularly profitable. In this case, especially, there is a wide margin of inaccuracy when an attempt is made to apply the initial figure over large areas.

Interestingly enough, our studies have shown that the average depth at which pocket gophers run their burrows beneath the surface of the ground is 6 inches. And this, I am informed by Prof. John S. Burd, is the usual depth reached by the farmer of California when he plows the land for his crops. Not only does the gopher bring raw soil to the surface to be further weathered, thus releasing the mineral food that the plants require, but it is continually burying vegetation beneath the earth which it throws up at the mouths of its burrows; and furthermore, vegetation is cut into pieces and carried below ground in large quantities by gophers, much of which is not eaten but remains there, just as does the vegetation which is turned under by the plow, to add to the humus content of the soil. All the excreta of a pocket gopher are deposited underground in special branches of its tunnel system, also at about the same critical depth—6 inches. The nitrogenous supply from this animal is thus not wasted in any such proportion as it is in the case of those herbivores which live altogether on the surface of the ground. It must be emphasized that it is on *wild* land, land that is untouched by the farmer, that the gophers thus serve in a valuable way as enrichers of the soil.

While the gopher and ground squirrel when they eat grass admittedly come into direct competition with horses, cattle, and sheep, the story does not stop there. An important function, it seems to me, performed by burrowing animals is that of counteracting the packing effect of large mammals on uncultivated grazing lands. The impact of heavy feet on the soil, especially when wet, crowds the particles together and renders the earth less suitable for plant growth. Close tamping tends to exclude the air and hence to suffocate the plant roots, to which oxygen is as essential as it is to animal life. One has but to observe the conditions on mountain meadows outside the limits of national parks to appreciate the point here made. Often where the country has been overstocked with cattle or

domestic sheep, the grasslands have become poor—the crop of grass is scrawny—*except* where gopher workings occur; the sites of these are marked by patches of vivid green. Indeed, on ordinary hill slopes I have repeatedly noted the rejuvenation of the plant cover here and there, traceable directly and obviously to the activity of burrowing rodents. Before the advent of the white man with his cattle and horses a similar service was rendered, though in lesser degree, perhaps, because of the less need for it, when the deer, mountain sheep, and bears frequented the same areas.

The question of damage to forests under natural conditions, for example, injury to young trees, is one that has been raised by foresters. There is no doubt but that gophers and squirrels do girdle or cut off the stems of many seedlings and thus terminate the existence of numerous individual trees. But the great number of seedlings observable on parts of any forest floor, vastly more than could ever reach maturity, would seem to indicate that an adjustment in this direction had been reached long ages ago. Plants in general provide for a rate of replacement sufficient to meet the maximum probabilities of casualty, this involving all stages from the seed to the mature fruiting plant.

In the arable lowlands of California the pocket gopher is well-nigh universally, and of course there rightly, condemned for pursuing his activities, in making his living, on lands that have been appropriated and cultivated by man. There, man has disturbed the original balance of natural relations between plants and animals; he aims to make the land produce crops of selected plants in the largest measure possible, and to that end he cultivates the ground himself by very effective “artificial” means. He naturally resents the levy upon the land and its products by any other animal. Most of the original quota of herbivorous mammals has been crowded out by his methods; but the gopher and ground squirrel have been able to persist under the changed conditions. Man’s crops have even increased their food resources; and they have been able to cope with the other changes. It is clear that we have here, most surely, a *reversal* of the relationships obtaining in the wild. On wild land there *is* no cultivation in the “artificial” sense. The crops of wild plants—grasses, herbs, shrubs, and even trees—depend upon whatever favorable agencies operate in natural ways. The happy relation found by our pioneers was the result of eons of adjustment among all of the elements concerned.

We grant that the farmer must combat the gopher and ground squirrel in his fields and gardens; we sympathize with him for yearning for the total eradication of the rodents there; and we will

help him in every conceivable way to control them. But we do not agree with the policy of wholesale extermination advocated by some persons for all areas alike. We hold that our native plant life, on hill and mountainside, in canyon and mountain meadow, would soon begin to depreciate, were the gopher population completely destroyed. Not that such a thing is at all possible; but that it should not be thought of, even, by any intelligent person who seeks to interpret nature correctly. Much less should public money be spent for such a purpose. On wild land the burrowing rodent is one of the necessary factors in the system of natural well-being.



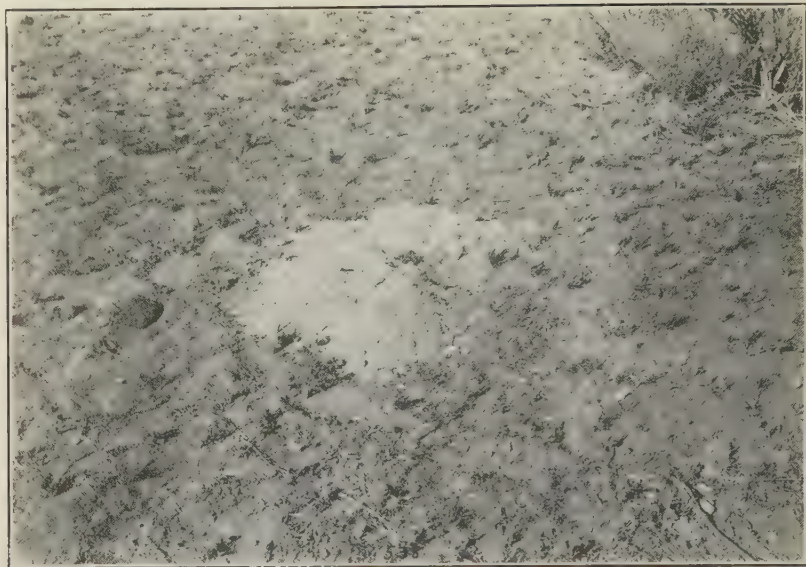
1. ILLUSTRATES EXTENT TO WHICH THE GROUND MAY BE WORKED OVER AND PERFORATED BY BURROWING RODENTS (IN THIS CASE *DIPDOMYS* AND *PEROGNATHUS*)

Photo taken by J. Grinnell May 4, 1911, near Earlimart, Tulare County, California



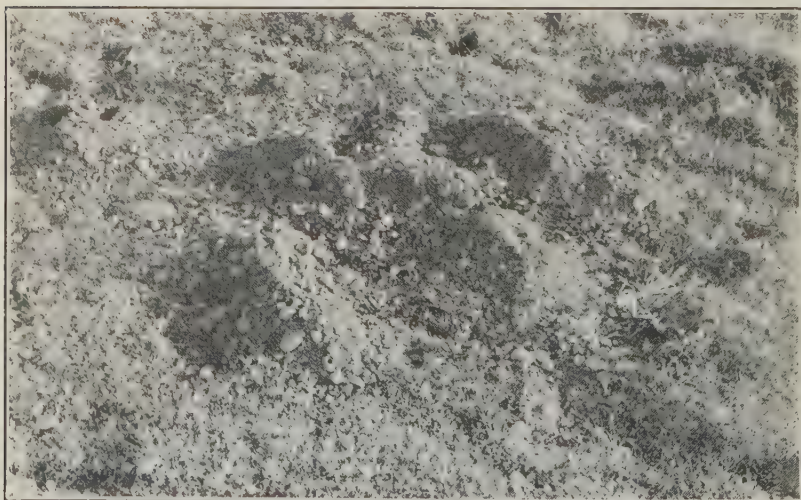
2. A POCKET GOPHER, *THOMOMYS BOTTAE PASCALIS*, PHOTOGRAPHED FROM FRESHLY TAKEN SPECIMEN TO SHOW CERTAIN STRUCTURAL FEATURES; FOR INSTANCE, UPPER INCISORS PROJECTING BEYOND FURRY ORIFICE OF MOUTH.

Snelling, Merced County, California, May 28, 1915. Photo by C. D. Holliger



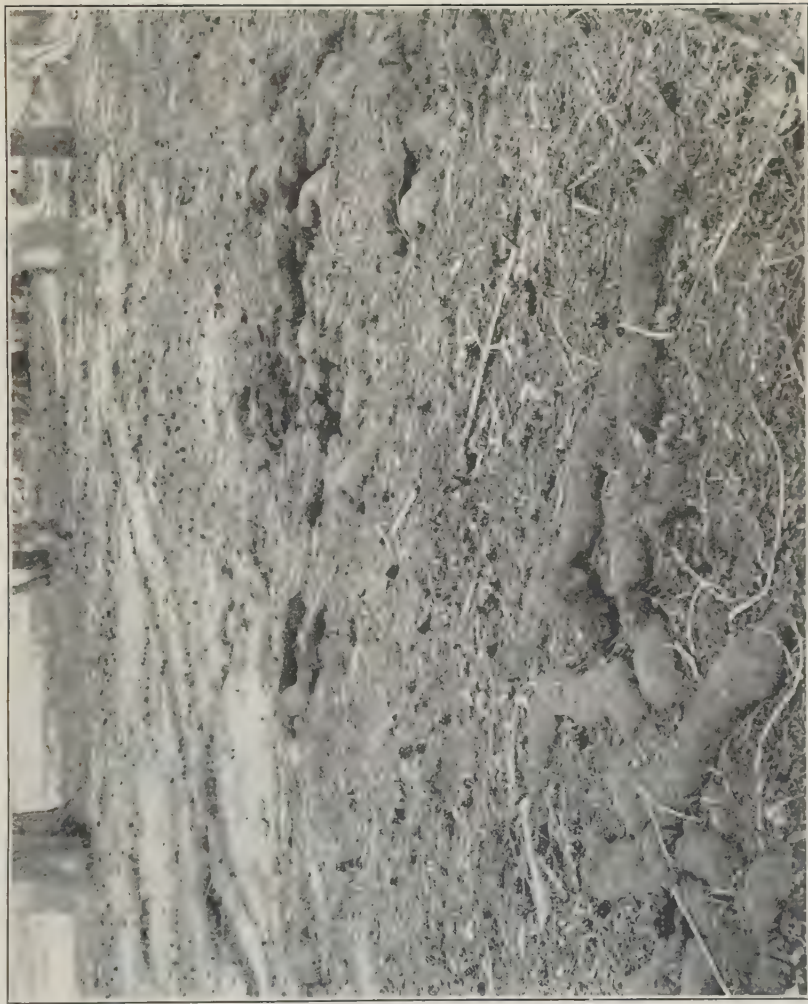
1. ILLUSTRATES THE WAY IN WHICH THE BURROWING RODENTS TURN OVER THE SOIL; A LIGHT-COLORED SAND FROM BELOW IS DEPOSITED, UNCONFORMABLY, ON TOP OF THE DARK-COLORED SURFACE STRATUM. THE POCKET GOPHER HERE CONCERNED WAS *THOMOMYS PERPALLIDUS PERPES*

Photo taken by J. Grinnell June 21, 1911, near Onyx, Kern County, California



2. IN THIS CASE A STONY SUBSTRATUM IS BROUGHT TO THE SURFACE WHERE ITS RATE OF WEATHERING WILL BE HASTENED; IN OTHER WORDS, THE PRESENCE OF BURROWING RODENTS IS ACCELERATING THE PROCESS OF SOIL FORMATION AND THIS, IN COURSE OF TIME, WILL MEAN IMPROVEMENT IN THE CROP OF NATIVE GRASSES OR OTHER PLANT GROWTHS. THE POCKET GOPHER RESPONSIBLE FOR THIS WORK WAS *THOMOMYS BOTTAE MINOR*

Photo taken by J. Dixon December 12, 1917, near Gualala, Mendocino County, California



THE WINTER EARTH-PLUGS HERE SHOWN, AS LEFT WHEN THE SNOW MELTED ON THE LODGE-POLE PINE FOREST FLOOR, SERVE TO BURY MUCH VEGETATIONAL DÉBRIS: WITH SUBSEQUENT DECAY OF THIS ORGANIC MATERIAL THE HUMUS CONTENT OF THE SOIL IS INCREASED

Such a process of binding up soil from beneath, of consequent gradual settling of the surface, and of burial of vegetable remains parallels quite closely in final results, on wild land, what the farmer does when he plows his cultivated acres. The pocket poplar doing the work in this particular case was *Thomomys monticola*. Photo taken by C. D. Holliger June 19, 1915, near Mono Meadow, Yosemite National Park, California

THE NATURAL HISTORY OF CHINA¹

By ARTHUR DE CABLE SOWERBY, F.R.G.S., F.Z.S.

[With 4 plates]

The subject we have before us is a very big one, far too big for anything approaching justice to be done to it in the time at our disposal. It may even be argued that the time is not ripe for anyone to attempt to deal with the natural history of China as a whole; that our knowledge of the subject is still too fragmentary; that it is both unsafe and unwise to try and form any far-reaching theories as to the origin, distribution, past and present, and the present status of the animals that inhabit this part of the great Asiatic land mass; in short, that a great deal more research work has to be done, both in the field and laboratory, before a general survey of the fauna of this ancient land can be brought within the compass of a single discussion.

This, to a certain extent, is true, for there undoubtedly remains a vast amount of work to be done in China before it may be said that even the vertebrates are all known; while a much greater time must elapse before the invertebrate fauna has been thoroughly explored. Nevertheless it is utterly erroneous, not to say unfair to past workers in this wide field of research, to say, as has been done recently, that the natural history of China is practically unknown. It is true that in certain groups of animals, for the most part orders or families of invertebrates, the Chinese representatives are unknown, but our knowledge of others, birds for instance, is actually nearing completion, and it is hoped to show here that this knowledge, coupled with what we know of the faunas of other countries and their distribution throughout the ages, is amply sufficient to enable us to draw conclusions and put forward theories, tentative though they be, in regard to that of China.

China is a very big country and comprises within her boundaries a very varied topography and many kinds of climates. In the west mighty mountains rise to heights far above the snow line; in the northeast lie immense alluvial plains; in the south and southeast the country is all broken up by irregular systems of hills and low

¹ Reprinted by permission from the Journal of the North China Branch of the Royal Asiatic Society, Vol. LIII, 1922.

mountains. Mighty rivers traverse the land from end to end, cutting through mountain ranges to form deep gorges, or widening their beds to form great valleys. In the north a temperate climate prevails, a warm summer being followed by a bitterly cold winter, while in the south tropical conditions are met with. The climate of the north may be characterized as dry, that of central China as humid, that of the southwest as distinctly wet. The result of all this is the presence of an extremely varied fauna, not only in regard to the species and genera of the families and orders represented, but in those families and orders themselves.

Another factor which helps to bring about this wonderful variety in the fauna of China is the age of the country. It is customary, when discussing the Chinese, to credit them with a very ancient civilization, but geologists tell us that the antiquity of China's civilization pales into insignificance as a world wonder when compared with that of her rock formations. It is not meant to suggest by this that the animals found in the ancient rocks have survived to the present time, but that in China we find animals still living that belong to very old groups. Even in the case of warm-blooded vertebrates, which, geologically speaking, are very recent, we find species belonging to a bygone age, an age that we call prehistoric. We find animals that belong to an age when man used only stone implements, and lived in cave shelters, the Paleolithic age. Such animals have only survived in these regions by taking shelter in the highest mountain ranges. The famous takin (*Budorcas*) is one of these, the giant panda, or cat-bear (*Ailuropus melanoleucus*) another. The lagomorphs—pikas and hares—belong to this group, as also do certain of the rodents, such as the allactaga, or jumping rat, and some of the voles.

Thus it has become customary for naturalists in the museums of Europe and America to look for and expect all kinds of remarkable forms of animals from China, and, periodically, some such animal is discovered. This happens in all branches of animal life. A typical example is that of two species of flea. A rat was caught somewhere in South China, and it was found to contain specimens of a peculiar jigger flea in its ears. These specimens were lost, and never again have similar ones been found. Quite by accident some white maggotlike creatures were found in the nostrils of a roe deer that I shot while on the Clark Expedition in Shensi. These were kept and later were examined at the British Museum, when it was found that they were enormously swollen females of a small black flea that infested the coat of the deer upon which they were found. The species has not since been secured. Other peculiar Chinese animals will be mentioned later; for the present let us continue for a moment

to consider the paleontological side of our subject, since this bears so strongly upon the present distribution of the animals of China.

It may be taken that a fair amount is known about the fossils that occur in the older formations, since several able paleontologists have been devoting their time to this branch of study. A geological museum has been started in Peking, as well as a geological survey of the whole of China, and already a considerable amount of valuable material upon which experts are now working has been gathered. It is the more recent formations, however, that most interest us here, since it is from them that we may find out when the animals we now know to exist in the country arrived there, and also what forms immediately preceded them. Unfortunately these recent deposits have not as yet been well worked or explored, though some interesting results have already been obtained. Thus we learn that the porcupine, now not known to occur north of the Yangtse Valley, once inhabited the province of Chihli, numerous remains of the animal having been found in recent deposits round Peking. Such a discovery is significant, for it shows that at no very distant date, geologically speaking, that part of China had a very much warmer climate than it has now. Couple with this fact my recent discovery in the imperial hunting grounds of northeastern Chihli, of a species of squirrel (*Tamias*), which belongs to a genus that does not occur elsewhere in China north of Ssuchuan in the west and Chekiang in the east, and it becomes obvious that the forests of west, central, southwest, and northeast China were at one time connected, a belt of heavy vegetation and trees probably extending all the way from Indo-China to the borders of Manchuria.

While exploring in Manchuria, I secured a specimen of a large bear that could not be classed either with the brown or the black bears of Asia. It was undoubtedly a grizzly, but up to that time the living grizzlies were supposed to be confined to North America. I was able to show that this bear was indeed a true grizzly, and also that there were other grizzlies in Asia. This very clearly shows how the grizzlies came to be present in North America, for these Asiatic forms are undoubtedly connecting links between the prehistoric grizzlies or cave bears of England and western Europe, which became extinct only after the fourth glaciation, and the living grizzlies of North America. The only way in which the latter could have acquired their present distribution was by the migration or, perhaps it would be better to say, the gradual spread, of their ancestors from Europe across Siberia or central Asia to the American continent by way of the land bridge that once existed where the Bering Sea now lies.

This land bridge was a very important factor in the present distribution of the animals of both America and the Eurasian land

mass. By its means such animals as the camel and the horse, both of which first developed in North America, and subsequently became extinct in that continent, arrived in Asia, the horse passing on to Europe, where it became the servant of man, and was subsequently reintroduced into America by him.

When we come to examine the distribution of the cold-blooded vertebrates, such as reptiles and fishes, we have to go further back in the geological history of the country in order to understand its significance, and it is here that our want of knowledge is most keenly felt. Nevertheless, a few interesting facts may be culled from what we already know, facts which throw a certain amount of light upon the subject.

An examination of the map of the Old World will reveal the fact that a desert belt stretches from Morocco in North Africa right across Asia to the borders of Manchuria, where it stops within a hundred miles or so of the sea. It has been suggested that it was this desert belt, known to be of considerable age, that prevented the *Urodela*, or tailed amphibians, from spreading south from Europe and north Asia into Africa and India. Force is given to this contention by the fact that it is only in the extreme eastern part of their range in Eurasia that they occur south of the desert belt in question, for there they found a stretch of humid country by means of which they could spread southward with safety. It is easy to see how such animals as newts and salamanders, which depend entirely upon the presence of ponds, streams, or lakes, wherein to lay their eggs and where their young develop, and which themselves can not exist in any but a humid environment, would find it utterly impossible to cross a stretch of dry, sandy desert.

Incidentally it may be mentioned that another animal that appears to have been influenced in its distribution by this desert belt is the roedeer (*Capreolus*), whose range extends from the extreme west of Europe throughout that continent, central Asia, north of the deserts, and Siberia into Manchuria. Thence it turns south and west, extending into north China and on into eastern Tibet. This deer does not occur in central or south China, its range being bounded in this direction by the Tsing Ling Mountains.

Reptiles represent a very old group of animals. One instance in connection with their ancestry and distribution may be mentioned here. It is that of the little Yangtse alligator. The *Crocodylidae* represent almost the very oldest living group of reptiles, and they acquired their distribution upon the face of the earth a very long time ago. It is believed that they originated in the Old World, spreading into the New World at a very remote period. These New World members of the group are mainly alligators or caimens,

though true crocodiles are also found in American waters. Since, however, there is one alligator to be found in the Old World, that from the Yangtse, it is obvious that at one time this genus enjoyed a very wide distribution in both the Old and the New Worlds, and that in some way the Old and the New Worlds were connected at that time.

Paleontology has proved of the utmost assistance in determining how the distribution of fishes, both marine and fresh-water, came about, though as yet nothing very important in the way of fossil remains of this type of cold-blooded vertebrate has been found in Chinese strata. Nevertheless, it is believed that China formed a center of dispersal for the great carp family (*Cyprinidæ*), receiving at the same time an influx of Silurids, or catfishes, from the region of the Indian Ocean.

We may next consider for a while the question of the faunistic areas that occur in China, or to which parts of China belong. Many years ago a distinguished naturalist divided the globe up into great faunistic regions such as the Palearctic, including practically the whole of Europe, and central and northern Asia, the Ethiopian, including Africa south of the Sahara, the Oriental, including India and Malay, and the Nearctic, including North America. Since that time it has become customary to go on dividing up these regions into subregions or faunistic provinces, often, it must be admitted, with but poor success. Notwithstanding this fact, we may make some such attempt in the case of China, for, even if certain groups of animals are not amenable to such a treatment, others undoubtedly are, and it will greatly assist us in our examination of the Chinese animals if we can discover the presence of such faunistic areas.

As a matter of fact the task is not a difficult one, for some very striking faunistic barriers occur in China. One of these is the great Tsing Ling divide that extends from the highlands of the Tibetan border through southern Kansu, and southern Shensi into Honan. North of this divide we have one group of animals, south of it another. It forms the boundary line of the ranges of a large number of both mammals and reptiles. For instance, we have already seen how it marks the southerly limits of the range of the roe deer. At the same time it forms the northerly limit of the range of the muntjac, another small deer, and the porcupine. To the north of it the animals are Tartarian in their affinities, to the south they are oriental. In the Provinces of Kansu, north Shensi, Shansi, Chihli, and Fengtien, the westernmost Province of Manchuria, we find such animals as the allactaga, the suslik, the gazelle, the wild sheep, animals which denote the intrusion of a Steppe fauna. At the same time we have the roe deer, the wapiti, or red deer, the wild boar.

and the fur squirrel, which suggest a forest fauna, and connect this part of the country, faunistically, with Europe by way of Manchuria and Siberia.

Central China, which may be taken as coinciding roughly with the basin of the Yang-tse-Kiang, is again characterized by the presence of certain forms, while when we come to the extreme south we find typically Indian or Malayan animals appearing. The animals of central China seem to have spread eastward and northward to a certain extent, which accounts for an intrusion of oriental species into Manchuria, as for instance the black bear and the sika deer. These may, however, have arrived in Manchuria from south China by way of the low-lying coastal provinces of the east. In any case we are fairly safe in dividing China up into three main faunistic areas, north, central, and south, noting that the northern animals are partially Tartarian, or Mongolian, the animals of central China being typically Chinese, and those of the south being partially Indian or Malayan. And there we may leave the matter, since nothing is to be gained by stressing the point too far.

Before making a rapid survey of the more prominent and interesting orders, families, genera, and species of animals occurring in China, it would be well to consider briefly the work done upon our subject by past field naturalists, experts in the museums of Europe and America, and others, at the same time taking note of the literature that is extant. The names of men like Père David, a Jesuit missionary who traveled over a great part of China studying the fauna and making collections which were sent to the Paris Museum, and Robert Swinhoe, a British consul, who also was a keen student and collector, stand foremost in the annals of the zoology of this country. David's material was worked out, as regards the mammals, by Milne-Edwards, the results being published in a fine tome called "*Recherches sur les Mammifères*," and, as regards the birds, by himself and Oustalet in their "*Les Oiseaux de la Chine*." Swinhoe's writings appeared for the most part in the *Ibis*, the organ of the British Ornithologists' Union, sometimes in the *Proceedings of the Zoological Society of London*. Since their time very little sound work was done upon the mammals till about the year 1907, when Mr. Malcolm P. Anderson, working for the British Museum, came to China and commenced a series of explorations, making magnificent collections, which were worked out by Mr. Oldfield Thomas, of that institution, who published numerous papers in the *P. Z. S.* and the *Annals and Magazine of Natural History*. The birds, on the other hand, have claimed many devoted students, amongst the most famous of whom are C. B. Rickett, J. D. de La Touche, and F. W. Styan. These ornithologists have contributed very considerably to

our knowledge of the birds of China, their published papers appearing usually either in the *Ibis* or the *Bulletin of the British Ornithologists' Club*.

A naturalist whose name must be mentioned was Père P. M. Heude, founder and first curator of the Zikawei Museum of Natural History. He managed to get together a very fine collection of Chinese animals, and published extensively upon the material that he gathered round him in the museum. Unfortunately he entertained somewhat peculiar views upon what constitutes a species, which led him to describe an enormous number of new forms on grounds that no modern naturalist can accept. Thus the value of his writings was seriously impaired, though the fine series of specimens in the museum remain a monument to his zeal as a curator and collector. His principal publication was his "*Memoires concernant l'Histoire Naturelle de l'Empire Chinois*," and he dealt mainly with mammals, though birds, certain reptiles, and certain fresh-water mollusks were also touched upon.

As regards the cold-blooded vertebrates of China, the most important names are those of G. A. Boulenger and C. Tate Regan, of the British Museum, and L. Stejneger, of the United States National Museum, whose writings upon the fresh-water fish, amphibians, and reptiles are to be found scattered through numerous scientific journals. The earlier workers upon the reptiles and batrachians were Cantor and Günther, and upon the fishes Günther, Valenciennes, Bleeker, Basilewsky, and Richardson.

Besides all these naturalists, there are a great number who have contributed to the literature upon the zoology of China, but it is impossible here to give all their names, or even an adequate idea of the vastness of that literature. A partial bibliography of the ornithology of China, which Doctor Richmond, of the United States National Museum, very kindly prepared at my request, contains the titles of over 700 publications, which are scattered throughout numerous journals, or have appeared in book form. It is almost certain that no library in the world contains a complete set of all the publications upon the fauna of China, though that of the Natural History Museum at South Kensington (British Museum) is remarkably replete with this form of literature. The libraries in China, alas, contain very little in this line, far too little to enable anything serious in the way of research work to be done. The geological department in Peking is trying to form a good working library, while the Zikawei Museum has a fairly useful one. The library of the late Dr. G. E. Morrison, of Peking, contained a good collection of zoological works on China, but it was sold and taken away to Japan. This lack of the literature upon the subject is a very serious handicap to anyone trying to do original research in the country, while another serious

handicap is the lack of collected material in the way of good series of properly labeled specimens for purposes of comparison. I should like to see an awakening of the interests of the members of the Royal Asiatic Society (north China branch) in regard to this matter, for this institution is obviously the one to lead the way, in this part of China at least, in the study of the zoology of the country, and all that is needed are adequate funds for the purchase of books and papers and to send collectors out into the field to gather more material. The society's museum already has a considerable amount of valuable material, but much more is needed before it can be considered as a genuine working museum rather than a show place.

MAMMALS

The mammalia of China is a comparatively large and varied one. It contains representatives of numerous families and genera, some of them unique, and most of them extremely interesting. Probably the great order Rodentia is most fully represented, though the Carnivora are extremely abundant, especially in some localities. The Ungulata, or hoofed animals, on the other hand, are less plentiful, a fact due doubtless to their value as food. The Chinese are not to be classed among the world's best hunters, but by reason of their numbers, and the fact that they never lose an opportunity to turn an honest penny, they soon destroy the big game in any district where such occur and they are allowed to hunt it. At the present time it is only in remote mountainous areas, more or less inaccessible to the outside world, that any of the larger ungulates are to be found in a wild state, and even these are being assiduously hunted by local natives, who are gradually acquiring modern rifles, and so threatening them with extermination. To this category belong the Asiatic wapiti, or red deer, several forms of which occur in the country, the wild sheep, the takin, the serow, the sika deer, and the goral. The large deer are hunted for the sake of their horns when in velvet, the Chinese believing in this commodity as an excellent tonic and rejuvenator. Thus the spotted deer, or sika, have become extremely rare, and are now only to be found in a few isolated areas. The sika deer form an interesting genus that is confined to the southeastern part of the Asiatic land mass and adjacent islands. There are two distinct subgroups within the genus, one containing the large animals of north China and Manchuria, and the other small animals, typified by the little Japanese deer. In the extreme southwest of China we find an Indian form of deer, the sambhur, while in the Yangtse Valley occurs the remarkable little river deer (*Hydropotes inermis*), which has no horns, but well developed tusks in the male. Muntjacs, musk, mouse deer, and roe deer complete the list of cervine ungulates that occur in China, the roe being confined to the north,

the musk to the north and west, and the others to the central and southern parts. The famous David's deer (*Elaphurus davidianus*), known to the Chinese as the Mei, or Ssu-puhsiang, meaning the "four unlikes," has become extinct, at least in a wild state. This and the river deer are purely Chinese forms, the wapiti being European and North American in its affinities, the musk Himalayan, and the sika, the muntjacs, and the mouse deer oriental.

Wild swine of the *Sus scrofa* type are almost universally distributed throughout the country. Antelopes and wild sheep belong to the north, the serows and gorals to the highlands, where such occur, and the takins to the highest mountain ranges of central and west China. The yak occurs in a wild state in the highlands on the Tibetan border, and the wild ass in Chinese Turkestan.

The Carnivora are represented by several important groups, namely, the Ursidae, or bears; the Canidae, wolves, foxes, and dogs; the Mustelidae, or weasels and their relations; and the Felidae, or cats. It would be interesting to follow out the various branches of this order, but neither time nor space will permit of it. Sufficient it is to note that in this group of mammals, as in the last, China possesses some remarkable forms all her own. Such an animal is the great panda, or cat bear (*Ailuropus melanoleucus*) of the Tibetan borders. The small panda (*Ailurus fulgens*) is another. The tiger was at one time, as the leopard is to-day, almost universally distributed, but now it is only rarely found in the north and central regions, though one form is common in the south and southeast, while the Manchurian forests contain numbers of the great woolly tiger. Small cats and civets are extremely abundant in the southeast; less so in other parts.

Of the Chinese rodents the most interesting are some of the voles and their not very distant relations the molerats (*Myospalax*) and the bamboo rat (*Rhisomys*). It is perfectly obvious from a comparison of the two forms that the molerat is a development from the bamboo rat, it having carried the specializations of the latter for a subterranean life a considerable step further. The bamboo rat, living in the dense jungle where it burrows for its food, the roots and shoots of the sword-grass, frequently stays above ground since it is well protected by the heavy vegetation. The molerat, on the other hand, having pushed northward, where vegetation is very much more scarce, has been forced to become almost exclusively subterranean in its habits and mode of life, and thus has become even more molelike than the bamboo rat, developing larger burrowing claws in the forepaws, and almost losing the external ear and the eye. In central, south, and west China all kinds of rats, more or less related to the common rat, predominate, but in the north we have an intrusion of Mongolian or Steppe forms, such as the jumping rats, *Dipus*

and *Allactaga*, the gerbils (*Meriones*), and the ground squirrel (*Citellus*). Here also are to be found the various members of the hamster family, rats characterized by the presence of large cheek pouches. Squirrels are universally distributed, characteristic forms being the huge flying squirrels, David's squirrel, the fur squirrels, and the chipmunks. The largest rodent in the country is the porcupine (*Hystrix*), which occurs throughout the Yangtse Valley and in south and west China.

Closely related to the rodents are the lagomorphs, or hares and pikas. These used to be classed with the rodents, but are now looked upon as belonging to a different order, whose development was, nevertheless, closely parallel. There are numerous subspecies of the common hare (*Lepus swinhoei*) in China north of the Yangtse. South of that river occurs a totally different animal, namely the Chinese hare (*L. sinensis*). This is a rather unique distribution and division of habitats, since the rim of the Yangtse basin and not the river itself usually forms the boundary line between the ranges of any two forms of animal in China. Apparently the Yangtse River has proved sufficient of a barrier to keep the one form to the south and the other to the north, and this in spite of the fact that hares are well known to be expert swimmers.

The pikas (*Ochotona*) are really small hares or rabbits, and they are confined to the north and the higher regions of the center and west. Strangely enough they occur on the flat plains of Mongolia, in the lowest ravines of Shensi and Kansu, in the forested areas of Shansi, and also at the very summits of the highest mountain ranges. This is evidently because they belong to a very old group of mammals, and so have had a long period in the country in which to spread and adapt themselves to all kinds of environment. They once inhabited Europe, but became extinct there along with all the other "steppe" animals. Now they are confined to certain parts of Asia and North America.

The bats and insectivores are two other groups of mammals that are well represented in China, some very remarkable forms of the latter occurring in the west. In the north hedgehogs and shrews are fairly common, as also are certain forms of mole. One of the most interesting of the Chinese insectivores is the peculiar *Neotetracus sinensis* from the west, which combines the characters of the shrews and the hedgehogs.

Of apes and monkeys China does not boast a large number or variety, though it is interesting to note that the most northerly representatives of this great group of mammals in the world to-day are to be met with in this country. In the area to the northeast of Peking, known as the Tung Ling, the fine Chihli macaque still occurs. In Ssuchuan the famous golden-haired monkey (*Rhini-*

pithecus roxellanae), one of the only two known monkeys that possess a nasal appendage, is found. This is a very large animal with a long tail and sometimes a long mane of golden hair down the back. In the southwest of Yunnan, on the Burmese border, several species of ape and monkey occur, while in the south and southeast others are to be met with.

While discussing the mammals mention should be made of the remarkable scaled ant eater (*Manis*), also called the pangolin. This creature is highly valued for its supposed medicinal properties. In fact, in certain parts of China every wild animal that is at all uncommon is credited with medicinal properties, and fetches good prices in the market. Thus the blood of the serow is considered very valuable, as also are the blood, bones, and claws of a tiger, the horns of the serow and goral, and the antlers of the stag. The pangolin is confined to the south and southeast.

In the matter of marine mammals, the seas that wash the shores of China are not very rich. Sea lions and common seals occur round the coast, while various kinds of whales and dolphins are to be met with further from land. Some extremely interesting river dolphins occur in the waters of the Yangtse basin. Some of these have not yet been identified. Certain lake forms suggest that at one time this part of China was under the sea, the dolphins being left behind in lakes when elevation of the land took place.

BIRDS

The birds of China are better known than any other branch of her fauna, apparently for the reason that they have attracted more attention from competent naturalists. It is probable that birds, insects, especially butterflies, and shell-bearing mollusks the world over have received more attention than other animals for the reason that they are more attractive. Whatever the cause, the fact remains that there is little to be expected in the way of new species of birds to be discovered in this country, though a great deal of work still remains for the ornithologist to do. For instance, the problems of migration in this country have scarcely been studied as yet, while the exact ranges of the indigenous forms of bird that occur have yet to be determined. No country in the world offers a better field for research to the ornithologist than does China. This country is the headquarters of the great pheasant family, while its great variety of topography offers the opportunity of studying its avi-fauna under all kinds of conditions from open desert to dense forest, high mountain ranges to swamps and flat lands. Breeding operations may be watched, nesting haunts and conditions noted. Bird life is so abundant that the student of nature need never be at a loss, unless it be through an *embarras de richesse*.

I have heard it stated that there are some 1,200 descriptions of birds from China. Whether this be the case or not, it is probably not very wide of the mark to set the number of distinct forms known to occur in the country at well over 600. In a list of birds that are known to occur in Manchuria and the neighboring region, which I have prepared with the help of various experts, there are some 500 forms. Most of these occur at least in some part of China proper, and it is certain that the indigenous birds of the more westerly regions must number considerably over 100 more.

The avi-fauna of China may be characterized as typically Palearctic with a strong intrusion of Oriental species in the southern parts of the country. At the same time the palearctic element may be further described as being Tartarian in its affinities in the north and northwest, and Himalayan in the highlands of the west and central areas. The importance of this Himalayan intrusion should not be overlooked, for it will often explain the remarkable occurrence of some species in an unexpected area. Botanists tell us that in the higher parts of this country the flora is often distinctly Himalayan, and this is to be explained by the fact that the Tsing Ling and other high mountain ranges of central and west China are apparently offshoots of the great Himalayan massif. We thus find that faunistic areas or zones occur in a perpendicular direction as well as a horizontal one, a fact first pointed out, I think it was, by Elwes, an ornithologist of considerable repute in England.

As regards migrant species in China, it may be pointed out that the country receives influxes of birds from India as well as the islands of the Indian-Pacific Oceans. Species that winter in the Philippines, for instance, are commonly found breeding in the mountains of north China. The whole of the China coast during the migration season forms an immense highway for transient visitors, which are on their way to Siberia to breed, and it is due to this fact that we know as much as we do about the number and kinds of birds that pass through China. It has been possible for observers who have been employed either in some European firm at the coast or in the customs service to devote their spare time to this fascinating subject, usually with very valuable results.

It is impossible here to go into details concerning the various families, genera, and species of birds to be met with in the country. The subject is too vast. Besides it would be superfluous, for there are numerous excellent lists of such birds extant, not to mention expansive works such as Gould's "Birds of Asia." The museum of this society contains a very fine collection of Chinese birds, and anyone wishing to take up the subject will find that the specimens have all been identified and labeled.

It has already been stated that China is the headquarters of the pheasant family, and if any one point more than another characterizes the avi-fauna of the country it is this. Perhaps another characteristic that may be mentioned here is the number and variety of the timaline birds—babblers, laughing thrushes, and the like—that occur. In the southern provinces we have such remarkable birds as the crow-pheasant, crow tits, and trogons, nor should we neglect to mention the numerous and beautiful flycatchers that inhabit this part of the earth.

The birds of northeast China, Corea, and Manchuria are remarkably similar to those of Europe and the British Isles, and a study of the subject reveals the fact that closely related forms, each grading into the next, occur all the way from western Europe through Siberia to these easterly regions.

REPTILES

In dealing with the reptiles and amphibians, or batrachians, of the country we are confronted with a rather remarkable fact. North of the Yangtse Valley these forms of animal life are very poorly represented, if not in numbers of individuals at least in variety of species, while south of it there is a great abundance of both. The explanation is not far to seek, and it lies in the climatic conditions to be encountered in the two areas. These cold-blooded vertebrates are a weak remnant of the great reptiles that lived in the days when the earth was much warmer than it is to-day, when the climate was far more humid and vegetation infinitely more luxurious and prevalent. Life for these great saurians was comparatively easy, and so they did not evolve any means of protecting themselves against the less favorable conditions that followed the Carboniferous and Cretaceous periods of the earth's history. Their descendants survived, but, with the exception of the crocodiles and alligators, only as very small replicas of the great monsters that once swarmed. And these survivors can no more withstand severe climatic conditions than could their ancestors. Only a comparatively few reptiles have been able to adapt themselves to a desert environment, and, even so, usually in warm countries. The bitter cold of the north China winter is too much for them. Similarly amphibians originated in the dense tropical jungles, swamps, and forests of the Carboniferous age, where their particular mode of reproduction and development from an egg laid in the water through an aquatic stage to a land animal was evolved. This they have retained, but they, too, have become greatly reduced in size and can only live where a congenial environment is to be found. Thus the dryness of the north China climate is inimical to them. Central China, on the other hand, offers much more favorable conditions to both reptiles and amphibians, and so we have a corresponding increase

in the number and variety of the species that occur there. But it is in south China that we find ideal conditions for the cold-blooded land vertebrates, and here these animals swarm. The museum of this society contains a very fine herpetological collection, thanks to the energy and enthusiasm of Dr. Arthur Stanley, the recent curator. But it is interesting to note that the greater part of the collection was made in the Province of Fukien, where semitropical conditions prevail, vegetation is extraordinarily thick, and plenty of permanent streams occur. In a valuable paper by Doctor Stanley upon the Chinese reptiles in the museum, some 72 species are listed, of which 49 have Fukien against their names. This does not mean, however, that they are confined to that Province, for specimens of many of them have been obtained elsewhere as well.

A glance at this list reveals the fact that of the various forms of reptiles represented in this country, snakes predominate. Fifty-one of the seventy-two species listed are snakes. These snakes range from the monster python, a specimen of which from Fukien measures 20 feet, down to the tiny blind snake. The majority of the species are nonpoisonous, but several very deadly forms occur. Amongst the latter are the black cobra, recorded from Chekiang and Fukiën, and the terrible Chinese viper (*Ancistrodon acutus*), whose poison fangs are enormous. Other poisonous snakes occurring in our region are the sea snakes, which are only to be found in the sea, and have become adapted to a marine pelagic existence by a lateral compression of the posterior part of the body and tail. The nonpoisonous snakes are mostly what are called colubers—grass snakes and water snakes—and are easily recognized by the usually slender bodies and heads.

Lizards of various kinds are fairly common, amongst the commonest in the north being the spotted lizard (*Eremias argus*) and the little gecko, the latter inhabiting the dwellings of man. In the south occur the blue-tailed skink (*Eumeces chinensis*) and its near relative, the elegant skink (*E. elegans*). Another fairly common form is the long-tailed lizard (*Tachydromus septentrionalis*).

Of the turtle family China contains several forms, including the mud turtle, some terrapins, and tortoises. Marine turtles are to be taken at times in the China seas, or are washed ashore occasionally on the southern coasts.

There is no need to do more than mention the little Yangtse alligator here, as we have already referred to it. The only other member of this family, the *Crocodylidae*, which occurs in China, is the estuarine crocodile, which is to be found in the rivers of the extreme south. Its scientific name is *Crocodylus porosus*. The difference between the alligators and the crocodiles, externally, is twofold.

The alligator has a much broader snout than the crocodile, while its fourth tooth from the front in the lower jaw fits into a pit in the upper jaw; that of the crocodile into a notch.

The amphibians in China are represented by numerous species of frogs and toads, or tailless batrachians, as they are usually called, as well as by a few newts and salamanders. The tailless batrachians greatly predominate, however. Remarkable forms are the little fire-bellied toads (*Bombina*), the little tree toads (*Hyla*), and the great tree frog (*Rhacophorus*), which is as large as a good-sized toad and has its long toes webbed and knobbed at the tips, thus enabling it to climb with agility. In the hills and mountains of Fukien and Chekiang a huge frog, not unlike a bullfrog, occurs amongst the damp rocks at the very summits of the ridges and peaks. Everywhere the edible frog, the smaller brown frogs, and the Asiatic common toad are to be found. In the north Radde's toad, a beautifully marked species, is very common.

The commonest of the Urodela, or amphibians with tails, is the Chinese newt (*Diemictylus orientalis*). A very handsome spotted salamander also occurs.

Mention should be made of the remarkable giant salamander (*Megalobatrachus davidi*), which, with the Japanese form, *M. japonicus*, is the largest of the present day amphibians. This creature has been recorded from central China, a closely related form occurring in the east. Both are very rare, at least in collections. The Japanese form is more common, live specimens being frequently exhibited in collections in Europe and America.

FISHES

The subject of the fish, marine and fresh-water, of China is one of extreme interest and importance. Its importance lies in the fact that the Chinese depend so largely upon fish to supply them with the necessary animal matter in their food. Of course the Chinese are not unique in this, but owing to the numerous fine waterways and large lakes that the country contains and her immense seaboard, with a resultant magnificent supply of fish food at hand, they have become fish eaters, in places to the exclusion almost of any other kind of animal food. Thus the fishing industry of the country is of great importance, which in turn means that a thorough knowledge of her finny inhabitants is vital to the future welfare of her people. As a matter of fact the fishes of China are rather well known, though it is obvious that there are many new discoveries to be made in this branch of the country's zoology.

The marine fish of China, that is to say, those occurring in the China seas, are closely related to those of Japan, which means that they are well known, for the Japanese and American scientists have

made a very thorough study of this subject. Many of the forms that are taken in China seas are of very wide distribution, others very local. The Clupeidæ, or herring family, is represented by a number of species, but it is not a very important group. The same may be said of the Gadidæ, or cod family, and the Pleuronectidæ, or flat fishes, families that are very important in the European and North American fisheries. The Perciforms, fishes that conform to the general characteristics of the perches, such as basses, maigres, rockfishes, sea breams, and the like, are of the utmost importance. One fish that should be specially mentioned is the hairtail (*Trichiurus*), the long, silvery, ribbonlike fish that one sees so frequently for sale, either in the dried form or fresh, in China. It is taken some little distance out at sea, apparently in large numbers, and is a great favorite with the Chinese. As one works northward along the east coast of Corea toward that of the Primorsk and the Okhotsk Sea the marine fish fauna undergoes a profound change in its composition. Flat fishes, herrings, gadoids, or cods and their relations, become the important elements, while there is a remarkable increase of members of such groups as the liparids, blennies, cottoids, and agonids. At the same time we find the Pacific salmonoids appearing, and running up the rivers to spawn, in exactly the same way as they do on the coasts of Alaska, British Columbia, and the north Pacific Coast States of America. In other words, the marine fishes of the Manchurian region show strong affinities with those of North America.

The fresh-water fishes of China are in many ways unique, or, perhaps it would be better to say, China possesses a somewhat unique fresh-water fish fauna. It is overwhelmingly cyprinid in its composition, the carp family having reached a high stage of development in these parts. It is impossible to give a list of the peculiar cyprinids that occur in Chinese waters, but a few forms may be mentioned. The gigantic *Elopichthys bambusa*, which resembles in its external characteristics a salmon, and reaches a length of 4 or 5 feet, and a weight of over 100 catties, is one. The peculiar *Hypophthalmichthys molitrix*, whose generic name means the fish with the eyes on the under side, is another. This species also attains a great size. China also possesses some very remarkable gudgeons, one of which is very long and slender in the body, and has a long snout, which gives it the appearance of a sturgeon. Breams, chubs, carps, culters, bitterlings, minnows, and loaches are all represented, many of them by genera purely Chinese. It is maintained that China was one of the centers of development and dispersal of the ciprinids, or carp family, and from a survey of its fish one might well believe this to be true.

Next to the carps come the catfishes, or Siluridæ. Here again China contains a great variety of species, though, taken as a whole, they have nothing like the economic value of the carps.

Other groups of importance are the so-called Chinese perches, which are in reality basses, certain cottoids, or bullheads, and the serpent heads.

Of isolated species the little *Polyacanthus opercularis*, from which the Chinese have bred the paradise fish, and the peculiar ganoid *Psephurus gladius*, which inhabits the Yangtse and the Yellow River, and whose only other near relation is confined to the Mississippi, are worthy of mention. The distribution of the latter species and its near relation is interesting, as it is exactly that of the alligators, of which we noted that one form occurs in the Yangtse and the other in the Mississippi basin. It may further be noted that the ganoids, like the alligators, belong to a very ancient type.

In connection with the fishes of China I should like to point out to the members of the Royal Asiatic Society that the museum contains practically no specimens of these forms of cold-blooded vertebrates, and though the present acting curator, Dr. Noel Davis, and I are trying to remedy this defect, it would be a splendid thing if some one would undertake to look after this branch, for of all the things the Shanghai Museum ought to have, a good collection of fish, both marine and fresh-water, is one of the most important. In this branch, if in no other, lies a fine field of research, for it has an economic as well as a scientific importance that none can deny.

INVERTEBRATES

We may now consider for a brief space the invertebrates of China. Had my line of research in China been more in the direction of the invertebrates, this lecture would have been devoted almost entirely to them, for, important as the vertebrates are, they pale into insignificance when compared with the lower forms of life. Yet, sad to relate, the latter have been very much neglected. Zoologists have almost invariably gone after the higher types of animal life, treating the lower forms more or less as unimportant side lines. This is a great pity, for the country is particularly rich in its invertebrate fauna, and would well repay work done in this direction. It is true that one or two branches of invertebrates have been well worked, notably in the case of the lepidopterous insects and seashells. Other branches of insect life, however, have been badly neglected, while almost nothing, or, at least, very little, is known about the terrestrial mollusks. What little is known shows that the land snails of China are of vital importance in the matter of determining how the fauna of these parts acquired its present distribution. Here, then, is another field of research open to some enthusiast.

One other very interesting branch of zoological study that the country offers is that of the marine and littoral invertebrate fauna. This is a branch that many of the members of this society, and of the whole Shanghai community, for that matter, might take up without undue expense or exertion, for most people spend some of their holidays at the seaside, where marine forms of life are thrust upon one's notice. The museum has some good material in this line, but what is wanted is some one to take up this branch and go into it thoroughly, and I can promise that person that he or she will be amply rewarded. Museums at home are crying for such material, and it would be a very easy matter to work in cooperation with experts in America and Europe, and so hasten the day when we can say that the natural history of China is an open book for all who will to study and enjoy. May that day soon come, and may the north China branch of the Royal Asiatic Society, as practically the only scientific society in the country, do its part.



YOUNG MANCHURIAN TIGER. KIRIN FOREST



A FINE RAM OF THE MANED SHEEP OF NORTH SHANSI AND SOUTH MONGOLIA, SHOT BY A. DE C. SOWERBY



YOUNG MANCHURIAN BLACK BEAR



THE MANCHURIAN CHIPMUNK



THE MANCHURIAN BLACK WATER SNAKE, OVER FIVE FEET IN LENGTH,
AND OF A BRILLIANT YELLOW AND BLACK COLOR



THE CHINESE PANGOLIN OR SCALY ANTEATER, FUKIEN PROVINCE, SOUTH-
EAST CHINA



THE MANCHURIAN RINGED PHEASANT



SOME YALU FISHES

Above, Herzenstein's catfish. Center, the Pike Gudgeon. Below, the Beaked Carp

LIFE IN THE OCEAN¹

By AUSTIN H. CLARK

PREFACE

A comparison of the animals living in the sea with those inhabiting the land brings out at once a most extraordinary paradox.

About three-fourths of all known kinds of animals live on the land; but this formidable array represents only a few of the major types. The most numerous land creatures are the insects, of about half a million sorts. Equal in importance, much larger, but much fewer both in kinds and numbers, are the vertebrates. Next in significance are the nematodes. Of much less importance are the mollusks—snails and slugs—and the annelids—earthworms, land leeches, and onychophores. The representatives of the other major types found on the land, planarians and nemerteans, are not of much importance in the picture as a whole.

While in the sea there live less than one-fourth of all the animals that so far have been described, these are widely distributed among about three times as many major types as are those inhabiting the land.

Certain marine types, like sponges, cœlenterates and polyzoans, and some groups of annelids, are sparsely represented in fresh water, which also has some types, like gastrotrichs and the rotifers, quite or almost wholly restricted to it. But of the major animal types no less than 10 (priapulids, sipunculids, phoronids, brachiopods, chætogonaths, echinoderms, enteropneusts, tunicates, and cephalochordates), nearly half again as many as all land-living types together, are exclusively marine.

On land different localities and situations are extremely variable as regards the physical conditions. We find hot, temperate, and cold, and uniform and changing, regions; dry, damp, and wet areas, permanent or changeable. All these features, together with the chemical variability of the soil, are reflected in the flora of the land, and all these features plus the superadded features of the flora, affect

¹ Reprinted, slightly abridged, by permission of the publishers, from *Animal Life of Sea and Land*, D. Van Nostrand Co., New York, 1924.

the animals. In consequence land animals have become subdivided into an indefinite number of different forms or minor types each most efficient within a small range of conditions.

But all land animals have one thing in common; they must seek their food; it will not come to them. Therefore land animals are almost wholly of those types, arthropods and vertebrates, best fitted for locomotion, with representatives of some other types of fair locomotor powers.

In the sea conditions are quite different. The temperature range is small. At no place temperatures of less than 28.4° are found, while high temperatures, even in the Tropics, are confined to a thin superficial layer. The great bulk of sea water ranges in temperature between 35° and 60° . The chemical conditions are only slightly variable. The salinity varies somewhat, but the different salts are everywhere present in about the same proportion. Motion affects only the surface waters, and is negligible except along the shores.

In the sea, food substances float everywhere suspended in the water, drifting back and forth and up and down; abundant food lies also on the bottom. While useful, powers of locomotion are not necessary for the creatures in the sea; if they can not seek their food it will be brought to them.

Thus in the sea the food relations of the animals are of three kinds; some go after it, as do the animals on land; some attach themselves or burrow in the bottom and let the water do the work of bringing food to them; and some float suspended in their food supply.

Three possible ways of obtaining food instead of one mean a corresponding diversity in the fundamental structure of the animals involved; but the relative uniformity of the physical and chemical conditions in the sea permit the existence of these major types with relatively slight subdivision.

THE BASIS OF LIFE IN THE SEA

What is the biological significance of a large whale? The immediate answer is that the largest whale, the blue or sulphur-bottom, is the largest animal known, living or extinct, reaching a length of 90 feet. The weight of such a monster has not been determined; but a torpedo boat of the same length with approximately the same underwater contour would displace 32 tons. If we assume a weight of 30 tons for the largest whale we shall not be far out of the way.

All whales are carnivorous; but all the fishes, cuttle-fish and smaller creatures upon which they feed, are dependent ultimately upon plant life for their existence. How much vegetable material does it take to support a whale?

If the 30 tons represented by a very large whale were incorporated in the bodies of cattle, these cattle would require for their support each day the amount of fats and carbohydrates present in the hay yielded by an acre of good meadow land in a whole season's growth. A whale requires much less food than its equivalent in cows, since it is entirely supported by the water and is much less active. On the other hand, consuming only other animals, many of which themselves are two or three or more steps removed from a vegetable diet, there is a very large wastage in the nutritive matter in the sea plants before it enters the whale. We shall assume that the latter offsets the former.

The State of Rhode Island has an area of 1,250 square miles. If this State were wholly planted in grass and yielded as much hay per acre as the average meadow, enough food would be produced in the course of a summer to support a maximum of about 2,150 of these great whales for a year; the District of Columbia could support less than 125.

Yet whales are abundant in certain regions. I have myself seen on the Pacific more than 100 at one time, though these were of a kind much smaller than the blue whale. At the height of the whale fishery at Spitzbergen the catch averaged slightly over 1,000 whales a year, all large ones. The food of those that were killed, not considering those left alive, would represent the annual grass crop from an area eight times the size of the District of Columbia.

These rough calculations are sufficient to show that the pastures of the sea must be very rich, for not only do the marine pastures support numerous whales of all sizes, but in addition various large sharks, a number over 40 and one over 50, and said to reach 70, feet in length, and other huge fishes which are not eaten by whales and therefore compete with them for the food supply. And then there are the seals and the sea birds and hosts of bottom-living animals in many places forming living carpets for miles and miles, all browsing, so to speak, directly, or mostly indirectly, on the same pastures.

It has been said that the marine pastures are richer than the pastures of the land, and on occasion this certainly seems true; but close comparison between the two is difficult. In the first place sea animals require much less nutriment than those on land so that comparison bulk for bulk between the two means little. Furthermore many whales and many of the larger fishes, like the mackerel and the herring, are migratory creatures, wandering regularly, or more or less irregularly, from place to place. On land the growth of vegetation with us ceases in the winter, and in the Tropics is much reduced in the dry season; nowhere is it uniform throughout

the year. In the sea the growth of vegetation also varies at different times or seasons quite as much as on the land.

On land all vegetation grows on the ground, or on some support fixed to the ground, and all animals live on or in the ground or among the plants growing upon it. Such animals as traverse the air do so only as a means of getting from place to place or, a very few, to feed upon others so engaged. The air, for all practical purposes, is a sterile medium. Potentially, however, conditions are quite otherwise.

In the city of Caracas, I was always greatly interested by the sight of festoons of plants, especially "wild pineapples" or bromelias, growing on the electric-light cables high in air and nourished only by substances extracted from the air. What does this signify? It proclaims the fact that wherever a plant can find support it can grow in the air just as well as on the ground, and suggests that if plants could only hover in the air like humming birds the atmosphere in the warmer regions would soon be converted into a dense jungle. Such a calamity is averted by the great weight of plant tissues as compared to air, which forces all plants to grow attached directly or indirectly to the ground.

Now water is 814 times as heavy as air, almost as heavy as protoplasm, the living substance of which both animals and plants are composed. Only the very slightest modifications are necessary to enable plants and animals to float about suspended at any depth in sea water, like the particles of mud in a muddy river.

The only plants we see in the ocean are along the shores attached to the rocks, like the devil's aprons or laminarias, the rockweeds, the sea lettuces, etc., or rooted in the mud like the eelgrass. The gulfweed or sargassum, so frequently seen floating in large patches on the north Atlantic, is in reality a rockweed from the Caribbean region growing feebly but never fruiting, and finally dying and going to the bottom, exactly as so many willow twigs would do floating on the surface of a lake.

Quite a number of creatures browse upon these plants along the shores, the largest of these being the manatees when in the sea, the sea cows and the dugongs. But it is obvious that the narrow fringe of seaweeds along the coasts can not supply the food of all the creatures upon which the whales subsist, much less the basic food of the myriads and myriads of other creatures with which the open ocean is populated. It is true that some of the brown seaweeds are very abundant, like the kelps on our New England and our western coasts, and some are of very considerable size, reaching 300, 400, or even 700 feet in length; but their actual mass when considered in relation to the food requirements of the sea animals is almost infinitesimal.

On pools and ponds and in quiet backwaters from lakes and rivers in the summer time the water is often quite hidden from view by the little floating plants called duckweeds or lemnas. Why do we never find floating seaweeds living in the same way? On a pond or lake, if the duckweeds are blown about by the winds, it does not much matter where they go; the conditions are about the same everywhere and some at least will eventually be washed into a backwater like the one from which they came. In the sea a floating plant, if not washed up on some beach, would sooner or later be carried to a region with a different temperature or with different chemical conditions where it would eventually die, just as the sargassum does. Large free-floating plants, requiring a large amount of nutritive matter and of sunlight and a more or less constant temperature, at least for considerable periods each year, such as are often so abundant in fresh waters, can not exist in the sea because of the certainty of eventual destruction through the impossibility of remaining continually within the narrow range of conditions under which alone their existence can be maintained.

But suppose the bulk of a 400-foot seaweed were distributed among several billions of microscopic plants. These would soon separate in all directions; some would sink to all depths below the surface, and those at the surface would be widely scattered by the winds and waves. Millions might be swept away and lost, but other millions would always be present constantly bringing forth millions of young. If small enough and distributed from the surface of the sea down to the limit of effective light penetration, about 650 feet as a maximum, and capable of rapid reproduction, such plants would be unloseable, so to speak, and always permanently present in any given locality.

This is exactly what occurs in the ocean. The great bulk of marine vegetation we can not see. It is composed mainly of plants called diatoms, especially prolific in cold regions and at cold seasons, of peridineans in the Tropics and at warm seasons, of the exceedingly small coccolithophorids, the very minute flagellates, and of other types.

The numbers of these little plants can only be imagined, not really appreciated. It has been calculated that in the water of Kiel Bay there are 6,336,000 diatoms alone per quart—or were at the time the calculation was made. If there are 6,336,000 diatoms in a quart of water, how many would there be in an area of the ocean the size of the State of Rhode Island, that is, 1,250 square miles, down to a depth of 650 feet, the depth to which at least they may be assumed to live?

Of course many regions are much poorer in diatoms than Kiel Bay, while many are richer; in the Arctic and in the Antarctic they may be so abundant at times as to color the water for miles and to give it a slight, but noticeable, "smooth" feeling.

The preceding paragraphs would seem to imply a static condition in the oceanic flora, which is quite the reverse of the real condition. The calculation given for Kiel Bay is for a single season only. In a given spot at times the sea may swarm with microscopic plants, while at other times it may be practically barren. In some places the difference in productivity at different seasons is almost as great as the difference in the productivity of your garden between mid-summer and midwinter. Usually the difference at different times is less than this, but the amount of plant life present in any given region of the sea is always very variable.

What are the diatoms? The diatoms are very minute plants which occur wherever there is moisture and light, in fresh, brackish, and salt water, on the moist surfaces of rocks, etc. The fresh-water forms all differ from those in the sea or in brackish water. Many kinds live attached, but many others float about suspended in the water, often in incredible numbers. The attached forms usually form a brownish stratum or a furry covering over plants and other objects in the water. In the Arctic the beginning of spring is foreshadowed by the brownish discoloration of the under surface of the ice due to a scum of bottom-living diatoms which have risen up and become attached to it.

The body of the diatom is inclosed within two lids or valves which fit together somewhat like the bottom and cover of a pill box. These are fashioned of silica, and are of the most exquisite beauty, often highly ornamented, and of various shapes, oval, crescentic, S shaped, linear, or wedge shaped, though most of them are naviculoid or canoe shaped. Most of the important pelagic diatoms form chains. Of a medium-sized species it would take 200 individuals in a row to make an inch; while a few are larger than this, many are much smaller.

Diatoms reproduce mainly by simple division into two, each of which in its turn divides into two, making four, and so on. The capabilities of this process may be appreciated when it is realized that if one diatom should divide into two in 24 hours, and its progeny do the same, in the course of a single month 1,000,000,000 would be produced.

So far as I am aware, the rapidity of multiplication of the marine diatoms under optimum conditions has never been satisfactorily determined. But it has been calculated that a single diatom may give rise to 1,000,000,000 in a month. With 6,000,000 diatoms, more or less, to a quart of water in such a locality as Kiel Bay, each one

with a reproductive capacity of roughly 1,000,000,000 per month, all of the diatoms could be destroyed except for a single one to each 166 quarts of water, yet in a month the full number would be again restored. This shows clearly the immense advantage the minute diatoms have over larger plants as floating organisms in the sea, and why it is that the marine vegetation, except along the shores, is all microscopic, and not only microscopic but extremely small.

The peridineans, coccolithophorids, flagellates, etc., while very different from the diatoms in bodily form and structure, are more or less similar to them in their relations to the marine world, so that it will not be necessary to consider them in detail.

While these little plants are able to increase at a most amazing speed and at times occur in incredible abundance, this only takes place under a small range of conditions, occurring for the most part at certain limited seasons. On land in many regions when the drought is broken by the rains, grasses and many other plants immediately appear in great abundance. Each grass blade is the equivalent in dry nutritive material of many million diatoms, and the synthesis or formation of nutritive material under these conditions is probably at least as rapid as it ever is at sea.

We live on land and are accustomed to strike an annual average of the conditions on our farms. The study of the sea is in its infancy, and we know it mostly from investigations in the spring and summer months. Until we know our seas throughout the year in detail we can not compare its potential productivity with that of our land areas.

THE INTERMEDIATE FOODS OF THE SEA

These floating, very small, sea plants occur in all localities, but they are naturally much more abundant in some places than in others. They are subject to great seasonal fluctuations in their numbers, and they become less common, many of them entirely disappearing, toward midocean.

They are so very small that, although their presence may convert the sea water into a thin living-vegetable soup, special adaptations are necessary to enable animals to feed upon them.

These adaptations are along three main lines.

Many animals of a structure very similar to that of these plants, some almost as small but others larger, live among them, entangling them in networks of slender sticky threads projected from their bodies. Such are the oceanic foraminifera and the radiolarians. Some of the peridineans, too, are incapable of synthesizing inorganic into organic substances, and therefore live upon the other little floating plants in the same way that rusts and blights live upon the leaves of plants on land.

Some animal types have given rise to very small forms which are able to pick out the little clusters of minute plants from the sea water. It is rather curious that the two animal groups to which, outside of the vertebrates, all the giants of the sea belong, the crustaceans and the mollusks, should have been the ones to produce the vast bulk of small creatures which feed upon the little plants.

Most numerous in kinds and numbers are the very small crustaceans of many different sorts which at certain places and at certain seasons occur in myriads and are present in greater or lesser abundance almost everywhere, and the very young stages of many of the larger ones—crabs, lobsters, shrimps, etc. Just as on land the insects are the chief intermediates through whose services plant substance is made available for spiders, scorpions, predaceous insects, and most vertebrates that are not plant feeders, so their close relatives, the crustaceans, are the main factors in the conversion of the microscopic plants in the ocean into a form in which their substance can be used by other invertebrates and by fish and whales.

Of these little crustaceans, the copepods are the most important, occurring in very great variety and in enormous numbers. Sometimes they are so very abundant as to give a pinkish or a red color to the sea for many miles, when they become important as a food for certain whalebone whales. The euphausians also, small delicate shrimplike creatures showing little variety, also feed on these small plants, and may be as abundant in bulk, though not in numbers, as the copepods. One of these, which in the springtime swarms in the fjords of northwestern Europe, then forms the exclusive food of the giant Blue whale in that region. The common rorqual, closely related to this monster and reaching a length of 70 feet, feeds partly on fish and is frequently seen feasting among shoals of herring which themselves are feeding upon the copepods and other small crustaceans which consume the plants.

Before leaving the copepods it should be mentioned that of all sea creatures they have shown themselves the most versatile in making use of reserves of food material. Besides the free-swimming ones, and the more numerous kinds of bottom-living ones, there are many that live in the food-collecting apparatus of the sea squirts, stealing the food gathered by them, in the digestive canal of crinoids, and in similar situations, while others become parasitic and often very large, and as "fish lice" prey upon the very creatures which, directly or indirectly, are feeding upon their plant-eating relatives, just as the bird bot flies live on the blood of insect-eating birds. One of these, in fresh water, lives upon the gums of the crocodile, which is relieved of its unwelcome presence through the attentions of the crocodile bird.

Besides the very small crustaceans, the chief plant eaters of the open ocean are curious and delicate little mollusks, the "sea butterflies," or pteropods, and their allies. But while some forms of these eat plants, most of them live upon minute plant-eating animals, mostly small crustaceans and other mollusks. There are, as compared with the crustaceans, relatively few kinds; but some of them occur in incredible numbers, and in the seas about Greenland and in other places they form an important part of the food of the whale-bone whales. So abundant are some of the shell-bearing species that in various parts of the Gulf of Mexico, the Mediterranean, the Bay of Biscay, and elsewhere the sea bottom is more or less exclusively composed of their dead remains, just as in other places it is almost entirely composed of the shells of the foraminifera or the frustules of diatoms.

The third method of devouring the minute oceanic plants is by filtering them from the water and thus concentrating them. The only oceanic animals that have recourse to this process are the salps and the appendicularians, queer creatures allied to the sea squirts, and certain of the smaller fishes, like the menhaden. Their straining apparatus is most wonderfully efficient, and it is surprising to learn, from looking at the contents of their stomachs through a microscope, how small is the size of some of the organisms they capture.

THE ANIMAL LIFE OF THE OPEN SEA

In the bodies of the small crustaceans, the pteropods and allied mollusks, the salps and their relatives, the foraminifera, and a few other types, the nutritive matter represented by the microscopic plants is reassembled into units of appreciable size. Upon these units, for the most part upon the crustaceans which represent the most abundant and most generally distributed of these units, feed all the other creatures of the open ocean, directly or indirectly.

Consuming these directly are larger crustaceans and mollusks, numerous fishes, the herring and herringlike fishes, flying fishes, the young of all, or nearly all, other marine fishes, etc., the larger salps, the jointed or annelidan worms, the nemerteans, the arrow worms or chaetognaths, the whalebone whales, the smaller jellyfishes, the ctenophores, and the very few pelagic echinoderms.

Upon these larger animals, but especially upon the fishes, live very large and formidable jellyfishes, many kinds of fishes ranging in size up to the basking-, whale-, and other giant sharks, reaching a length of from 40 to 70 feet, the smaller members of the whale tribe, the porpoises, dolphins, etc., and the squids and cuttlefish, some of which are very large, one reaching a length of 55 feet. The squids and cuttles form almost the entire food of the great sperm whale, the bottlenose, and the other toothed whales.

The fishes are the most omnivorous of all sea creatures, some kind or other eating every sort of oceanic creature, and every other product of the sea.

Jellyfishes are sometimes of enormous size, ranking with the largest of sea animals. At Nahant, Mass., Prof. Louis Agassiz measured one in which the bell was $7\frac{1}{2}$ feet across and the tentacles more than 120 feet in length; this was one of those reddish ones frequently seen on the New England coast in the late summer.

On and above the surface of the sea, especially in the cooler regions where life is most abundant, live great numbers of birds which are truly oceanic and never visit land except to nest. These are mostly of the tube-nosed tribe, albatrosses, shearwaters, petrels, diving petrels, etc., and some at least are familiar to everyone who has ever been anywhere at sea. Where ocean life is especially abundant there are multitudes of auks, puffins, murre, etc., in the northern regions, and of penguins in the southern. Some terns are almost pelagic in habit, like the noddy and the black-backed, and I have seen tropic birds hundreds of miles from land both in the Atlantic and in the Pacific.

These birds feed chiefly upon small crustaceans, since these are offered most abundantly. The albatrosses and similar large sea birds, however, eat mostly squid which they catch at night, and the other larger birds eat squid and fish when they can get them, especially the terns and tropic birds. But nearly all these birds will eat any sea animal of suitable size, or if divided or divisible into fragments of suitable size, and the floating carcass of a giant squid or whale affords a feast for thousands of them.

The only oceanic insect is a little water strider, related to the water striders of our ponds, which picks the small crustaceans from the sea and sucks their juices. Though small and inconspicuous, they are not rare, and I have collected many of them both in the China Sea and in the Caribbean.

But as yet the story of pelagic life is only half complete. The crustaceans for the most part are the intermediates through which the organic material synthesized by the minute plants is made available for the use of the oceanic animals. Each of the larger oceanic animals represents in itself an important reservoir of food for other animals. Besides the predaceous types, there are many creatures, especially crustaceans, that live within the stomachs of other animals, eating the food they swallow, and within the filter of the salps consuming the minute organisms they are concentrating for themselves. And in addition there are bizarre misshapen forms of very numerous sorts which live within the bodies of practically all the larger crustaceans, feasting on their juices, with sometimes others living in the

same way within them; while many, equally uncanny and deformed, live like lice sucking the blood of fishes, and others bore deep into the skin of whales.

Within the digestive tube of the fishes, whales, and sea birds live certain creatures not found elsewhere, except that some have been found to exist as larvæ within the bodies of crustaceans. These are the tapeworms, echinorhynchs, etc., which have no stomachs but absorb through their skin the nutritive fluids in the alimentary canals of their hosts.

In the middle of the day in the Tropics and in the height of the summer in the temperate regions most animals seek the shade and become more or less inactive; animal life is most in evidence early in the morning and again toward evening. At sea most animals, especially in low latitudes and where the sea is clear, seek the shade in just the same way, retreating far below the surface to the twilight zone in the daytime, reappearing at or soon after dark.

Midway between Bermuda and St. Kitts I have watched the sea for hour after hour without detecting a single living thing. But on one trip we stopped to pick up a buoy that had broken away from its moorings off New Orleans some years previously. Scarcely had the speed begun to slacken before all sorts of creatures began to appear in the shadow of the ship. A small light speck deep down slowly increased in size and was finally revealed as a 15-foot shark, which insisted, in spite of all discouragement on the part of the sailors, in accompanying the small boat sent out to attach a line to the buoy. Other smaller sharks appeared, together with the inevitable pilot fish, and a troop of those magnificently colored fish called by sailors dolphins, though in no way like true dolphins, which are small fish-eating whales. When the buoy was brought up to the ship the underside was seen to be festooned with growths, about which played many little fishes, and on being hoisted on board many kinds of animals were found among the "weeds." Almost as soon as the steamer got under way again everything vanished, and the sea became as deserted as before. But about a score of small sharks and as many pilot fish lay on the fore deck, evidence of the prowess of some of the Chinese women in the steerage.

On the Pacific in low latitudes we found that we were most successful in finding oceanic life in the daytime if we lowered our tow-nets to about 600 feet beneath the surface. In this region there is twilight even on the brightest day at noon, and it is at this or somewhat lesser depths that the sea animals for the most part seek refuge from the light.

The animals taken in a haul 600 feet or more below the surface in the daytime and in another haul in the same place taken on the

surface at 9 or 10 o'clock at night are not quite alike. Most of them are the same, but in the deeper haul there are to be found various large shrimplike crustaceans, mostly bright red in color, strange jellyfishes of a deep red, and different sorts of sooty black fishes, some armed with enormous teeth and most ferocious in appearance, others long and eellike, with snipelike jaws, and others looking more like ordinary fishes but with rows of brilliant phosphorescent lights along their sides; quite commonly there are also little distorted silvery fishes, also with lights, and sometimes little black sharks from 6 or 8 inches to a foot in length.

These creatures are representatives of the deep oceanic fauna which remains below the illuminated upper layers of the sea, feeding upon the surface animals when these descend in the daytime to escape the sunlight, and upon the smaller animals about them.

The oceanic plants can only live to a maximum depth of about 650 feet, and at that depth only in the most transparent water; but the animals which feed upon them form the food of other animals which live deeper, in perpetual shade, and these again furnish food for other, though fewer, animals which live still farther down, in perpetual night. The oceanic animals, largest as well as smallest at the surface, extend downward for an indefinite distance, becoming less and less varied and gradually scarcer and more uniform in size; probably, indeed, no level of the sea is entirely without them.

Well out of sight, but probably in the twilight zone where food is most abundant and conditions are practically the same in all the oceans except in the extreme north and south, live giant squids and cuttles of several kinds, the largest, occasionally found floating in a dying or dead condition in the autumn on the fishing banks and sometimes in other parts of the sea, reaching a total length of at least 55 feet, with the body 20 feet long and 12 feet in circumference and the eye opening 7 by 9 inches; in one individual measured the tentacular arms were 37 feet in length. In October, 1875, between 25 and 30 of these giant squid were found by the vessels of the Gloucester fishing fleet on the Grand Banks and cut up and used for bait. The schooner *Howard*, Capt. J. W. Collins, alone secured 5 of these, which were mostly from 10 to 15 feet in length, not including the arms. The schooner *Tragabigzanda*, Captain Mallory, secured 3 from 8 to 12 feet long in one afternoon. Probably as many were found by the ships from other towns as by those from Gloucester.

The famous sea serpent can from most accounts be identified as one of these great squid in a dying condition, somewhat distorted by an active imagination. The head with the frilled neck, so commonly described, is the tail of the squid lifted above the water.

The long slender snakelike sea serpents are the writhing arms of which the expanded ends look something like a head.

Another common sea serpent on the New England coast is a composite picture of two basking-sharks which, swimming one behind the other, sometimes appear as a single creature nearly 100 feet in length. Still other sea serpents are based on porpoises or dolphins, and on large tropical fishes.

Other inhabitants of the twilight zone are strange fishes, especially the ribbon fishes, which may reach a length of over 20 feet with a height of a foot or less and a thickness of only an inch or two at the broadest part. Ribbon fishes and their close relatives, the oar fishes, are found floating dead or washed up on the beaches in all parts of the world, and seem not to vary from one locality to another. Very young ones, queer looking things, are sometimes taken in tow-nets.

THE OCEAN AND THE LAND

On land there is vegetation everywhere except in the most arid regions, and even there a heavy rain is immediately followed by the appearance of plants of many kinds. The plants are always the most conspicuous living features of every landscape; but they grow only on the surface of the land, rooted in the soil or, more rarely, attached to some support or floating in the water.

In the open sea no plants are ever visible, save for an occasional dying rockweed torn from its moorings, though sometimes streaks and clouds indicate masses of diatoms or other minute plants individually invisible to the unaided eye. The visible life of the sea is entirely animal; but the microscopic plants, all of which drift freely about, exist in incredible numbers and occupy a broad stratum reaching a maximum of about 650 feet in thickness in the clearest waters of the Tropic seas, but decreasing to a much lesser thickness north and south where the water is less transparent and where the light is less.

Very few animals feed directly upon the sea plants, and of these only the minute crustaceans are of first importance. These, possessed of only feeble swimming powers, drift aimlessly about and may be said to furnish the chief, though a purely secondary, basis of marine life; though animals, they are to the ocean what the green plants are to the land.

In contrast to land animals, most of the smaller and many of the fairly large marine animals, such as the jellyfishes and the younger stages of such fishes as the ribbon fishes and the eels, are more or less transparent, some quite so, looking like glass models of themselves.

Never put your fingers into the catch of a tow-net haul without first knowing what is there. Once I was trying to catch a paper

nautilus without a shell, which was swimming about in a bowl of water containing material from a haul off south Japan, when my finger was violently seized by something. Exploration with a glass rod and a pair of forceps revealed the presence of a large and ugly amphipod an inch or so in length, entirely transparent, though as tough as any other.

From the surface of the ocean down to great depths animals exist, but the number of major groups and of species rapidly decreases and their size becomes more nearly uniform below the limit of light, until in the deeper layers only grotesque fishes, cuttle fishes, jelly-fishes, crustaceans, nemerteans, and echinoderms, all feeding on each other, are found.

THE SEA SHORES

The shores of the sea are bathed by the water from the open ocean, charged with microscopic plants and small crustaceans, and with such of the creatures feeding on these as are able to support the light of day. But because of the fact that the rocks and stones and mud, and to a lesser degree the sand, offer facilities for attachment, conditions here are entirely different from what they are in the open sea.

Along the shores an attached plant, as a result of the movement of the water about it, has constantly delivered to it a fresh supply of the dissolved substances necessary for its growth, and it is maintained permanently under conditions most suitable for its existence. Hence the enormous development of the brown, green, and red algæ, or "seaweeds." Some of the flowering plants, too, have become adapted to marine conditions, and one of these, the eelgrass, belonging to the pondweed family, forms extensive beds in suitable localities.

These plants are important in providing shade and hiding places for the animals found among them, and when alive they are eaten by a few mollusks, like the periwinkle, by a few crustaceans and fish, mostly under stress of hunger, by some sea urchins and, where these occur, by sea cows, manatees, and dugongs, by some turtles, and by a single lizard. When they die their leaves or fronds break up and the fragments form the vegetable detritus so very important as the basic food of the marine animals along the shores.

In the open sea the animals can avoid the dangers attending too violent wave action by simply descending to the quiet depths. Along the shores there is no escape from the constant movement of the water. This incessant turmoil on the shore line, however, is easily translated from a menace into a distinct advantage; animals simply attach themselves firmly to seaweeds, stones, or other objects, and let the water do the work of bringing food to them.

On land the most successful plants are the flowering plants, which grow by forming a series of units one above the other called *phytons*, by the multiplication of these units producing a rosette of leaves or a tall or branching leafy stem and thus exposing the maximum green surface to the sunlight and the air.

The sea water being charged with nutrient particles throughout, it is obvious that in the shallow regions any animals which are able to attach themselves and to produce in the same way as do the flowering plants an indefinite series of reduplicated units each more or less perfect in itself would be able to avail themselves to best advantage of the food materials drifting here and there and all around about them.

Attached animals, particularly animals that grow and look like plants, are especially characteristic of the sea shores. The so-called colonial animals along the coasts which, plantlike in their growth though in no other way, live firmly fastened and secure their food from the restless water as it washes back and forth, are the sponges, certain *coelenterates*, including the hydroids, the corals, the sea fans or gorgonians, the millepores, the sea pens or pennatulids, the umbellularians, the alcyonarians, the antipatharians, the colonial anemones, and some other types, the polyzoans, the phoronids, the rhabdopleurids, the cephalodiscids, and the colonial tunicates or sea squirts.

The sponges, all of which when alive possess a strong odor disagreeable to us, though it may be attractive to the little things on which they live, have the general mass (it can scarcely be called a body) pierced by numberless small holes leading into small tubes lined with extremely delicate hairlike structures, called *cilia*, beating inward. These small tubes lead into larger ones, and these finally into an opening leading to the exterior, through which a constant stream of water, impelled by the ceaseless action of the *cilia* in the small tubes, pours outward. On its journey through the canals of the sponge this water has lost a considerable portion of the nutritive particles which originally it contained. One does not think of muscular power in connection with the apparently motionless sponges. Yet on the reefs at Bermuda at low tide I have frequently seen the calm surface of the sea much agitated by a stream of water coming from below which investigation showed originated from the outlet of a large sponge.

This food-collecting system of the sponges is very efficient, and other animals take advantage of it. Jointed worms of many kinds, one a much-branched creature with a head on the end of every branch, live within the canals, as do various small crustaceans and brittle stars. Barnacles, embedded in the outer layers, and some crustaceans

with similar boring habits, as well as comatulids attached to the surface, all take advantage of the indraft of water into the small canals.

The polyzoans, phoronids, rhabdopleurids, and cephalodiscids are all provided with a tentacular apparatus, the tentacles being abundantly supplied with cilia which pick the food particles from the water and pass them downward along their inner side toward the mouth. The polyzoans, common everywhere, are leaflike or encrusting growths on seaweeds, etc.; the individual animals in the colonies are minute, but very numerous, and are often divided into various types, each suited to perform a special function. A few polyzoans are solitary, or occur in small colonies. The representatives of the other three groups mentioned above are mostly uncommon, local, or inhabiting rather deep water. In the phoronids and cephalodiscids the individual animals in the colony, though they all arise by budding from the same original individual and all live together in the same mass of tubes, are not connected with each other as in the polyzoans and rhabdopleurids.

The colonial tunicates or sea squirts form thick incrustations on a usually rocky base. They are provided with an exceedingly fine sieve through which they draw the water, separating out from it the food particles.

The colonial cœlenterates are very diverse in size and shape. The most familiar are the corals, millepores, red corals, and sea fans or gorgonians of the warmer seas, and on our coasts numerous kinds of hydroids, forming mossy or feathery plumes on seaweeds or on other objects. One of the last, dried, stained green, and placed in a flower pot, is the common "Japanese air plant" sometimes seen offered for sale. Other sorts of cœlenterates are the sea pens and sea feathers, dead men's fingers and other alcyonarians, horny corals or antipatharians, and the colonial anemones. All of the sea anemones and jellyfishes belong to this group, and indeed many of the smaller of the latter are nothing more than the sexual units which have been liberated from hydroids.

The stony corals are important in assisting to a greater or lesser extent in the formation of the immense coral reefs which are such a conspicuous feature in many parts of the tropical seas. Some of them grow to a huge size, though the living portion consists only of a relatively thin superficial layer. The stony axis of the red coral is familiar to all because of its use in jewelry. Some cœlenterates reach a very large size, certain gorgonians attaining a height of 15 feet, some sea pens being 6 or 7 feet or more in length, and some umbellularians more than 8 feet tall.

The colonial cœlenterates consist of a great number of sacklike units which have about the opening a row of 6 or 8 or more tentacles armed with formidable stinging organs, or of such units

intermixed with other types modified from them, borne upon a flattened, wandlike or treelike support. The units vary from very small, in the hydroids and millepores, to an inch or so in diameter; in the noncolonial forms they may be more than a foot across. The stinging organs, which paralyze as well as sting the prey, enable the *cœlenterates* to use as food much larger and stronger creatures than do any other of the animals which feed in this way, and they are wholly carnivorous.

The *cœlenterates* support many parasites, especially crustaceans, which live within their bodies or travel up and down their stems appropriating the food which they have collected, and brittle stars, especially adapted for clinging to them, while many animals attach themselves to them which are known to live nowhere else, yet which do not feed upon them, like certain anemones. Many small fishes and other creatures live among their branches, protected from their enemies by their stinging tentacles, while a wealth of different types, especially worms and mollusks, hide themselves away in the stony bases of the large corals.

A group of colonial *cœlenterates*, the so-called siphonophores, including the Portuguese man-of-war, one of the most formidable of all the jellyfishes on account of its unusually developed stinging powers, and a group of colonial tunicates, have adopted an oceanic life, and all the species drift about as true elements of the oceanic fauna.

Besides these colonial attached animals, there are many others which live attached, but never form colonies, though many are highly social.

The most familiar of these are, perhaps, the barnacles, some of which, like acorn barnacles, live closely appressed to rocks, piles, the carapaces of sea turtles, etc., while others, like the goose barnacles, formerly supposed to be the young of the barnacle goose, are stalked and are most frequently seen on floating bits of wood, on the bottoms of ships, and about the mouths of whales.

The barnacles have several pairs of curved feathery appendages with which they sweep small animals from the sea water. These featherlike structures, together with the color, which resembles that of a barnacle goose, taken in connection with the fact that this goose was not known ever to lay eggs—its nests have only recently been discovered in, for a goose, most unlikely places—gave rise to the idea of the connection between the two. The barnacles are crustaceans related to the copepods. In their young stages they are quite like other young crustaceans, but they undergo profound changes during growth. Some barnacles, which live on whales, bore deep into their skin to attain a better anchorage. Others bury themselves in the outer layers of sponges. Many others, become parasitic, when young bore into crabs and other large crustaceans and, losing all

semblance to others of their kind, develop a mass of roots through which, plantlike, they absorb the juices of their host.

The seapeaches and other large sea squirts are familiar to all fishermen on our coasts. They have a sieve inside of them by means of which they strain small organisms from the water, after the manner of the salps.

The brachiopods, which look like bivalve mollusks but are really very different, mostly live attached, though a few burrow into mud. Their food-collecting mechanism is in general similar to that of the polyzoans and phoronids, to which they are supposed to be related. One of them, called the snake's head, is very common in suitable localities on the New England coast below the low-tide mark.

Some bivalve mollusks live attached to firm supports, like the oysters of our shores, while many others, like the clams and razors, live buried in the mud. Some, like the mussels, attach themselves with slender silken threads, as all do when very young. The quahogs or hard-shelled clams, from which the Indians used to make their wampum, and other forms lie exposed in quiet places on the bottom. A few, like the sea dates or pholids, bore into rock and sometimes in great numbers into breakwaters, while the shipworms or teredos, which are not worms at all but mollusks, tunnel into wood and feed upon it, like the larvæ of boring insects in the forest trees. Most of the unattached bivalves can move about, though rather slowly; a few are quite active, like the razor shells, and the scallops are more active still, and can even swim.

Many worms, while not attached themselves, live in tubes of their own construction attached to other objects or partly rooted in the mud.

Of animals which live wholly exposed or hiding away in burrows, holes, and crevices and among the roots of plants, there are multitudes of conchs, whelks, drills, periwinkles, and other snaillike creatures, of crustaceans of very many sorts, and jointed worms of many different types, together with nemerteans, some of which are very large, priapulids, sipunculids, and flatworms. Fishes, of course, are everywhere.

Besides the abundance of attached animals, especially of the colonial types, the coastal regions are mainly characterized by the great development of three groups of animals which are almost or quite unrepresented in the open sea. These are the bivalve, the gastropod or snaillike mollusks, and the echinoderms, including the starfishes, the brittlestars, the sea urchins, the sea cucumbers or holothurians, and the crinoids. The first two are most abundant along the shore, becoming much less common in deeper water, while the echinoderms rapidly increase in relative abundance with increasing depth. Practically all the members of these three groups are sluggish animals, most of them able only to crawl slowly, though a few bivalves and

starfishes and the comatulids can swim freely for short distances; some, like oysters and most stalked crinoids, live permanently attached to other objects.

To mention in detail the economic interrelationships of all these creatures would be an overwhelming task; and, indeed, very little is known about them. But let us consider one or two examples.

The common mussel, like oysters and other bivalves, is preyed upon by the common starfish, which is often most terribly destructive, moving back and forth across the mussel beds in swarms and up and down the piles where mussels grow. We have no figures on the damage done the mussels, but in 1888, on the Connecticut coast alone, this starfish destroyed \$631,500 worth of oysters, after not less than 42,000 bushels of them had been taken from the beds. Mussels are preferred to oysters by the starfish, and some beds have been entirely destroyed by them. Various gastropods, oysterdrills, dogwelks, winkles, conchs, and others eat vast quantities, while killifish, cunners, scup, tautog, squeteague, flounders, and cod are very fond of them. In fact, mussels are excellent bait for fish. The walrus in the Greenland seas feeds exclusively on mussels, though the seals, like dolphins, feed on fish and squid. On our coasts mussels are eaten by rats and by such birds as large gulls, ravens, crows, and ducks.

Within the shells of oysters, pinnas, and the other larger bivalves live flatworms, known as "wafers," little crabs, small shrimps, and sometimes other things, most of which, except the first, are harmless, or at least do no more than steal the food that they collect.

The very bony crinoids would seem to offer little in the way of food for parasites, yet nearly 150 parasitic or semiparasitic forms have been described from them. A little groove runs down the middle of the upper side of the pinnules and the arms of crinoids, and the five grooves from the five rays converge to the central mouth. The minute creatures taken from the water are passed down along these grooves in a constant stream, which becomes richer and richer as more and more of the victims are delivered to it by the side branches, and at the mouth forms a rich plankton soup. Most of the crinoids' parasites are simply grafters, camping along the sides of this stream and sucking up the soup. About two-thirds of these belong to a curious type of worm, called myzostomes, which, except for three sorts, internal parasites in starfishes or brittle stars, are entirely confined to them. Crinoids support about two dozen kinds of crustaceans of several different types, a few of which bore into the soft parts, but most of which appropriate the food material they collect, either from their ambulacral grooves or from their stomachs. Nearly a dozen kinds of brittle stars have never been found except upon them, about a dozen kinds of small gastropods bore into them and suck their juices, and they support at least one internal worm and many protozoans. Barnacles,

hydroids, sponges, foraminifera, corals, rhabdopleurids, tunicates and bivalves, and curious polyzoans grow upon them, using them as a support to maintain themselves above the mud or sand. But crinoids have one distinct advantage over mussels in that fishes never eat them.

All sea animals are undoubtedly as complicated in their relationships to others as are the mussels and the crinoids; each feeds upon a more or less extensive list of organisms, and in its turn serves as a source of food for many others.

The enemies of the smaller animals are mostly the larger and predacious ones. The enemies of the plantlike types are chiefly the grafters and the food stealers. The enemies of the larger creatures, as the sharks and whales, are the much smaller blood-sucking or internal parasites which, though much less conspicuous, are very numerous and just as dangerous.

The birds of the seashores call for brief enumeration. The gulls, very numerous in northern regions, are chiefly scavengers, feeding upon whatever is cast up on the beaches or they are able to find upon the flats when the tide is out; ravens and crows compete with them along the shores, but are never very numerous, and are very much less agile on the wing; both these last two prefer to consume their booty in the woods, and often carry shells, starfish, and urchins for some distance inland. Terns and skimmers eat crustaceans and small fish, and fish and sometimes squid form the diet of the cormorants, pelicans, bobies, frigate birds, tropic birds, and gannets. The reef and night herons catch fish and various of the larger crustaceans, while the very numerous shore birds eat aquatic insects, crustaceans, marine worms, and small mollusks which they catch along the water's edge or on the rocks and beaches, some, like the phalaropes, also on the surface of the sea. Interesting, but relatively unimportant and not numerous in species, are the fish-consuming hawks, eagles, kites, and vultures. The osprey is known to almost everyone; so is the bald eagle, which often robs him of his prey as the parasitic skuas and jagers do the gulls and terns. In the Aleutian Islands this eagle is one of the most abundant land birds along the shores, and is much easier to shoot than the small birds, which here are very shy. In the harbors of the East the kites, soaring over the water on the watch for scraps, look strange to us, accustomed as we are to gulls alone. The condor and the California vulture frequent the beaches more or less, and the nests of the latter often contain mussel shells. Two of the cormorants, one, now extinct, but formerly common in the Commander Islands, the other living in the Galapagos group, one auk, formerly abundant on the north Atlantic coasts but now extinct, and all the penguins, are flightless.

Of other seacoast creatures there are the seals, which live on fish, the walrus, which live on mussels, and the sea otter, now very rare

and local, which eats largely, if not mainly, sea urchins. The sea snakes, true snakes and poisonous, yet true sea animals, most of them more helpless on land than eels, the seaweed eating iguanas of the Galapagos, and the coypu of the inlets of southwestern South America also deserve mention. But the most curious of all the seacoast creatures is the large fish-eating bat of the Caribbean region, which smells strongly of musky fish oil and is abundant at St. Vincent, where it spends the day in chinks and crevices in the sea cliffs which one would think much too small for it.

What is the vegetable basis of this abundant coastal life?

On our north Atlantic coasts and on the coasts of Europe this comes from four main sources.

1. Vegetable detritus, or the more or less decayed fragments of the plants growing on the bottom, the seaweeds and the eelgrass, suspended or dissolved in the water, lying on the bottom, or mixed with the bottom mud.

According to very careful investigations which have been carried on in Denmark all the bivalve mollusks, two snails, all the sea cucumbers, sipunculids, cumaceans, sea squirts, ostracods, polyzoans, sponges, and foraminifera, and the balanoglossids and cephalochordates, as well as the beach-fly larvæ, are purely detritus feeders; the great mass of material in their alimentary tracts when analyzed corresponds to the detritus on the ocean floor, and the free-floating plants are only incidentally present. In the deepest water the organic matter is probably chiefly derived from the free swimming organisms which die and fall to the bottom, and in places from the *Sargassum* and other rock weeds which have been torn from their moorings and have perished far from land.

2. Plants growing on the bottom, chiefly eelgrass where that occurs, upon which browse certain snails, like the periwinkles, a few echinoderms, and some crustaceans. The Danish naturalists have found that as a basis for the support of the shore-living animals these plants (especially the eelgrass, the most abundant on the Danish coasts) are next in importance to detritus.

3. Free swimming microscopic plants, similar to those of the open ocean. The Danes have found that these are of almost no importance on their coasts; their slight value is indirect, through the medium of the free swimming copepods. But probably elsewhere, especially in Arctic and Antarctic regions where there is no eelgrass and they are enormously abundant, they become of much significance.

4. Driftwood, floating or stranded in the water, and wooden structures, such as piles and wharves. These, essentially vegetable detritus, form the food of curious aberrant bivalves called shipworms or teredos, which bore into them and often cause enormous damage. Other bivalves and various crustaceans, such as the gribble,

bore into wood and are often quite destructive, but the teredo is the only creature known actually to live upon it.

THE DEEP SEA ANIMALS

In the open ocean there is abundant plant life at the surface, almost entirely composed of microscopic types upon which feed minute animals endowed with remarkable reproductive powers through which the organic matter is passed on to larger creatures. There are also floating seaweeds torn from the rocks and drifting with the currents, growing more or less, though never fruiting, which serve to some extent to feed the smaller creatures. The gulf-weed or *Sargassum*, so common in the north Atlantic, is the most familiar and important type.

Far below the surface in the twilight zone, where the daylight gradually fades to darkness and plant life disappears, in the levels to which most of the surface animals, at least in the clearer and more sunlit portions of the seas, retreat during the day, lurk many predaceous forms which never rise above it. Still farther down, in the cold perpetual night where the motion of the waves is never felt, the creatures of the twilight zone pass over into other types, all of medium size or rather small, all good swimmers, and all or nearly all with phosphorescent lights, like fireflies—strange fishes, squids, crustaceans, jellyfishes, etc.—which, becoming fewer and fewer, reach probably to the bottom, those of each level feeding upon the animals from the zone above, and all being supported by the creatures of the twilight zone which at night feed upon the plants. In the north and in the south where the cold water, filled with living particles, is less transparent, and the sun's rays strike it at an angle and do not penetrate so deeply, the twilight zone comes almost to the surface and there is little difference between night and day conditions.

Along the shores there is a greater or lesser abundance of large algæ or seaweeds of many sorts and of flowering plants living fastened to the bottom. These are constantly dying and, partially decaying, breaking up into fine particles, this detritus floating about in the water and finally coming to rest in the mud or sand. The microscopic plants of the open ocean, of course, exist here also, while many kinds of diatoms and similar types live on the bottom and clinging to the weeds. While a few animals here live by browsing on the seaweeds and the eelgrass, the dominant animal types are sluggish or sessile, or attached and usually arborescent plantlike animals, living on the bottom or traveling over it, consuming the detritus, with the more active animals consuming them, especially the shellfish, crustaceans, and echinoderms.

What happens as the sea floor sinks farther and farther from the surface?

The light gradually diminishes so that in the clearest and most sunlit seas, at about 650 feet, there is only a pale moonlight at noon on the brightest day, while at greater depths there is no light at all. Wave motion dies away, and not far below the surface there is perpetual quiet even in the fiercest hurricane. The temperature declines, rapidly at first and then more slowly; in the abysses it is mostly a few degrees above the freezing point—below it in some places. The pressure increases so that at 15,000 feet it is about $2\frac{1}{2}$ tons to the square inch.

The number of kinds of animals found between tide marks, in rock pools, on the beaches, or on piling, is relatively small, rapidly increasing from the high to the low water mark. Below the low-tide mark the variety of animal life is markedly increased. Beyond a slight depth, 50 feet or so, but varying in different places, within which there are often well-marked zones, some of the shore forms disappear, but other creatures take their places and still others constantly appear at greater depths. The maximum variety of marine animal types is found on bottoms between about 600 and 1,200 feet, where the light is dim to almost absent, the water is cool and very still, and there is abundant food provided by the shore detritus and the sea above.

Within this zone there are many animals of large size, crabs 11 feet or more from claw to claw, huge urchins and starfish, great plantlike things looking like small apple trees (*Primnoa*, etc.), masses of large crinoids, stalked and unstalked, and other creatures, and probably in certain places swimming about the giant squid and cuttles.

Below this zone the stillness of the water and the increasing pressure favor the deposit of the finest silt, and the bottoms are chiefly of fine mud, passing into the so-called oozes made up of the shells of the millions and millions of small creatures constantly dying in the layers above. The greater part of the sea bottom beyond the coastal muds is formed of globigerina ooze, consisting of the shells of minute shelled animals, the oceanic foraminifera, largely globigerinas, with some bottom-living types and a few other things. Less common are the pteropod oozes, made up of the shells of oceanic mollusks, the radiolarian oozes, and the diatom oozes. Toward the middle of the oceans the oozes gradually pass into an excessively fine red mud, which is the typical bottom of all the abysses far from land.

On the red mud everywhere and sometimes on the oozes lie scattered the ear bones of whales and the teeth of sharks, the only portions of these animals that will persist indefinitely. Some of the sharks' teeth on the red mud are of gigantic size, several inches in length, and came from species long extinct but known as fossils else-

where. On the ear bones and the teeth manganese slowly collects, in time inclosing them in characteristic nodules of various sizes. As over the red mud oceanic life is so very scanty as to be practically nonexistent, these nodules for the most part probably represent the remains of decrepit sharks and whales which have strayed out here and died.

Below the twilight zone the variety of animal life rapidly lessens, and, on account of the uniformity of conditions in all oceans at these levels, becomes practically the same everywhere.

The basic food here consists of detritus from the plants along the shores, decreasing rapidly in amount with distance from the land, and a correspondingly increasing amount of organic matter derived from the bodies of the creatures in the layers above which, dying, sink gradually to the bottom, where further decay is arrested by the perpetual cold and the great pressure which prevent, or at least inhibit, the action of bacteria. The foraminifera, pteropods, diatoms, etc., and the *Sargassum* and other floating seaweeds dying and going to the bottom carry there at least a portion of their organic substance, which mixes with the mud. This bottom ooze or mud when brought on deck seems absolutely clean, but in the warm air it soon gives forth a most offensive smell, proclaiming the organic matter it contains.

This mud is swallowed by many of the bottom animals, particularly by all of the numerous echinoderms, except the crinoids, and by many of the crustaceans, which digest the organic matter out of it, living in the same way that some of their relatives do along the shores and the earthworms do on land. For the other animals, such as the sponges, sea squirts, stalked crinoids, and coelenterates, intermediates are necessary to make this food available, and these intermediates seem to be the numerous forms of radiolarians and related types which, judging from the long stalks of the attached animals, must in some places form a thin mist for some distance above the sea floor.

Deep-sea animals are much more common near land off precipitous coasts than at the same depths farther out, in correspondence with the greater density of life in the layers above, and also under cold surface water. They are, after all, only littoral types with sufficiently adaptable natures to enable them to descend to the greatest depths, and fundamentally they differ very much less from the shore types than would be supposed. In the Tropics the difference between the littoral and the abyssal animals is great, and the change from one sort to the other rather abrupt, but in the cold regions many of the deep-sea types come up into shallow water.

The reasons why all sea animals are most abundant near the land and gradually decrease in abundance and in size with increas-

ing distance from the shores is that the nutritive material brought to the sea by rivers and washed from the land by rain upon which the plants subsist is most abundant here. On very precipitous coasts the detritus from the seaweeds falls into deep water and adds to the food supply of the deep-sea creatures, which elsewhere is derived only from the remains of oceanic organisms.

The ocean's deepest spot is 40 miles east of Mindanao, in the Philippines, where a depth of 6.08 miles (32,113 feet, or 5,352 fathoms) has been determined.¹

No animal life is known from such a depth as this. The animal from the greatest depth so far recorded is a fish (*Grimaldichthys profundissimus*) which was brought up from 19,806 feet, or $3\frac{3}{4}$ miles, beneath the surface in the north Atlantic by the late Prince of Monaco. Many other things, of course, must live at this depth also for this fish to feed upon. It is perhaps worthy of remark that a fish of the same type, a so-called brotulid, lives in fresh water in the caves of Cuba.

It was once thought that the abysses would contain many relics of past ages which had become extinct along the shores. But surprisingly few such relic types have come to light, and there are not nearly so many of them in the deep seas as are to be found along the shores and in fresh water.

Of all the animals of the ocean floors the mud-swallowing echinoderms are perhaps the most abundant and diversified and the most generally distributed; but all the groups represented also occur in shallow water except for a small number of minor types. The most conspicuous of these echinoderms, because most strange to us, are bizarre sea-cucumbers and starfish, and soft and flexible shelled urchins. Stalked crinoids rooted in the ooze or firmly attached to stones or other objects are characteristic of the deeps, but all the groups represented, like all of those to which the more abundant unstalked forms belong, come up into shallow water, with possibly one exception. The crinoids most important from the paleontological viewpoint, the *Pentacrinus* of our textbooks, and the curious *Holopus*, so far from being deep-sea animals, live, at Barbados, in 30 feet or less, so that they can be seen from the surface with a water glass.

Sponges with silicious skeletons are often very abundant in the deeps, especially near land. One of the chief trials of a deep-sea naturalist is sorting over a catch with these things in the mud. Their spicules are sharp as needles, glassy, and transparent, and scattered everywhere, so that the sight of sponges always means sore hands.

¹ On September 1, 1924, a new "deep" was reported 145 miles southeast of Tokyo. A sounding here by the Japanese steamer *Manshu* gave 6.18 miles (32,636 feet, or 5,439 fathoms).

Sailors, no matter how callous they may be toward other forms of life, quickly learn to recognize silicious sponges.

The coelenterates are the only group of animals of which a large proportion of the types are confined to deep water. They are abundant here, and of many different sorts. Especially characteristic are the sea-pens and umbellularians and the curious anemones. There are many corals, largely solitary ones, but no massive types, and numerous alcyonarians and allied creatures.

Various sea squirts occur, both simple and compound.

Crustaceans are abundant, of all the principal marine groups except the king crabs and the squillas, though barnacles are poorly represented. They are mostly blind and spiny. There are a few sea spiders or pycnogonids, some of which are very large; one single kind lives all the way from the shore line down to 13,350 feet below the surface.

Mollusks of all the principal groups except the pelagic occur; one type, called solenogaster, a wormlike thing living on gorgonians and apparently parasitic on them, is most abundant in deep water. The gastropods or snails, though there are no remarkable forms in the deep sea, are interesting in ranging from at least 16,000 feet below the surface uninterruptedly to above the snow line in the Himalayas.

The fishes are practically all of the bony or teleostean type, and chiefly represent modifications of forms represented at or near the surface in the cold and temperate zones, or which appear as nocturnal oceanic forms. They are small, mostly black or dark sooty brown, sometimes albinistic, blind or with large eyes, and often with long filamentous processes.

Of the remaining animals there may be mentioned the few brachiopods, less interesting geologically than the littoral ones, some sipunculids, the few annelid worms, mostly living in calcareous or quill-like tubes, the numerous radiolarians, and the foraminifera.

From this catalogue one might, perhaps gather the impression that animal life in the abysses is abundant, which is far from true. A net dragged for two or more hours over the sea floor, an operation consuming almost an entire day, may bring up less than a handful of animals, or even none at all. Rarely, and usually near shore off precipitous coasts, are rich hauls made.

Like their relatives in shallow water, the deep-sea animals, especially the echinoderms and sponges and pennatulids, tend to live in colonies. with various crustaceans, worms, etc., associated with them. Sometimes the dredge brings up only the dead remains of such a colony which has died from the exhaustion of the meager food supply, or from old age or other cause.

A STUDY OF THE FLIGHT OF SEA GULLS¹

By ROBERT C. MILLER

[With 4 plates]

No one who has traveled on the ferries which ply across San Francisco Bay can have failed to note the sea gulls which follow constantly in their wake. Hour after hour, day by day, sometimes at night even, they may be seen winging tirelessly after the cumbrous boats, sailing high like paper kites, or sporting in the currents of air about the stern, or scuffling noisily for bits of food thrown overboard by the passengers. In the earliest dawn they are on duty, looking like gray specters in the morning mists, and on moonlit nights they are abroad at least until midnight, flapping along like giant bats in the semidarkness.

Of the many thousands of people who have watched the gulls on the bay and admired their beauty, probably most have thought of their graceful evolutions only as a part of nature's artistry. But for the ornithologist, the æsthetic is not the sole nor even the principal interest which attaches to them. Rather does he remark the marvelous powers of flight which enable so large a bird to keep aloft for long periods of time without fatigue, and the rapid coordination which permits it to take advantage of every current of the shifting air, and to maintain its equilibrium under the most adverse circumstances of wind and weather.

On account of their large size, easy flight, and relatively slow wing movements the gulls have long been looked upon as peculiarly favorable subjects for studies of avian aeronautics. However, although our knowledge of their flight is rather extensive, as yet it is far from complete. The data assembled by different observers are frequently not in agreement, and, as Hankin (1913, p. 253) has pointed out, two authorities as competent as Maxim and Headley have published statements diametrically opposed. Such contradictory ideas must, in most cases, indicate not that the observations on which they rest are incorrect but only that they are inadequate; a type of behavior which is observed on one or two occasions may be entirely lacking

¹ Reprinted by permission from the Condor, Vol. XXV, January, 1923. The writer of this essay was awarded the Cooper prize in ornithology offered at the University of California in 1921-22 for the best study of any subject concerned with birds.

under other circumstances, and it would be a mistake to assume that modes and methods of flight adapted to some particular set of conditions hold true for all.

The writer became interested in some of these problems by watching the maneuvers of gulls about the ferryboats, and he began accordingly to take notes on their behavior with reference to the speed and direction of the wind and other factors, as he had occasion to cross the bay from time to time. The present paper is based on a series of observations covering a period of about nine months, from July, 1921, to March, 1922, during which time the writer has on occasion laid himself open to suspicion of mental aberration by rushing about on the deck of a ferryboat, gazing seaward and skyward, and jotting down notes in a small black book.

The machinery of flight—the structure of wings and feathers and the nice musculature which controls them—has been dealt with in much detail by Headley (1895 and 1912), Hankin (1913), and others. It is sufficient here to note that the wings are strong, rigid, and light, that they are curved to offer the maximum resistance on the downward and the minimum on the upward stroke, and that the great wing feathers, by their shape, contribute materially to the action of the muscles and relieve unnecessary strain. It is generally agreed that the muscles and tendons of the wing are so arranged as to operate automatically, the motion which extends the humerus mechanically extending the other units of the wing, even to spreading the flight feathers. (This view has been objected to by Beetham, 1911, p. 435.) It is important also to note that the tips of the flexible flight feathers bend upward under the strain of any sudden gust (pl. 2, F), thus allowing the wind to “slide off” from the under surface of the wing and contributing automatically to the maintenance of equilibrium.

Having in mind these few notes on the mechanics of flight, we may go on to consider the bird in action, which has been the major object of these studies. Nothing appears more leisurely and effortless than the flight of gulls. The exertion by which they keep pace with a steamer seems to be little more than an idle flapping, when indeed they are not soaring on almost motionless wings above the boat. But when we come to study more closely just what is taking place, and particularly when we record photographically certain movements that are too quick for the eye, we discover that more energy is being expended than at first seemed to be the case.

The first point to be noticed is that the stroke of the wings is considerably longer than appears to the eye; indeed, each time the pinions are raised the inner segments almost meet above the body, and on the downward beat the outer segments approach the perpendicular beneath it. This can partially be seen when a bird passes directly on

a level with the eye, but can be fully demonstrated only by photographs which catch the wings at their highest and their lowest points. The full sweep of the wings can be seen by a comparison of Plate 2, A and B, which indicate respectively the beginning and the completion of a stroke. This is illustrated a little less perfectly by the two birds in Plate 2, C; and in Plate 2, D, by a happy chance, five different phases of the stroke are represented, although neither the full upward nor the full downward extension of the wings is shown. It will be noted by studying the lowest bird in this figure that, on the down stroke, the wing is sharply flexed at the wrist, the forearm being nearly horizontal.

It should be remarked, however, that while the eye tends to underestimate the length of the stroke, the camera somewhat exaggerates it. The wing does not actually describe an arc of nearly 180° , as might be thought from its extreme upward and downward extensions. It is to be remembered that the body of the bird is not moving on a fixed plane, but undulates with each beat of the wings, rising on the downward stroke and falling a little as the wings are raised. This up and down motion appears from Marey's figures (1895, p. 237) to be about equal to the thickness of the body of the bird. Thus when the wings move from the highest to the lowest position of a beat, their tips describe a shorter arc than if the body were fixed. The undulating motion of the body is usually concealed from the observer for lack of a point of reference, or because it is masked by the greater motion of the wings.

From the fact that the wing stroke is as long as we have described, it follows that the beat must also be more rapid than it gives the impression of being. This is found to be true when we undertake to photograph a gull in action. The seemingly leisurely flapping of the wings can rarely be caught by an exposure of less than one two-hundredth of a second, and often shows movement at even higher speeds than this (pl. 2, E).

In ordinary flight a gull will average about 120 strokes per minute. This involves a rather slow movement near the shoulder, but one which becomes exceedingly rapid toward the tip of a long wing, as we see in Plate 2, E, and in the case of the lower right-hand bird in Plate 2, F, where the humeri are sharply recorded, but the more rapidly moving tips are blurred.

It is the rapidity of the wing stroke which is the secret of flight, not of gulls alone, but of birds in general. The quick stroke suddenly compresses the resilient air beneath the wing, and this has usually been assumed by theorists to be the means by which the bird is supported; it rides on successive columns of compressed air. Rather, however, should be emphasized the reciprocal of this; that is, that on the downward stroke a momentary vacuum is left above the wing.

In other words, the air pressure is removed above but maintained beneath the pinion, so that it is supported theoretically by a force approaching 14.7 pounds per square inch of surface. Of course, this vacuum is by no means complete and is of very brief duration, but it is obvious that the lifting power of the air beneath is ample to support a much larger bird than a gull on the same wing area.

The displaced air can not rush in so quickly in the wake of a large wing as in the wake of a small one. This explains why a gull is able to support itself in the air with only two strokes per second, while a sparrow, which really has a greater wing expanse in proportion to its weight than a gull, must take 13 strokes per second (Marey, 1890, p. 100). A large wing is intrinsically a more efficient instrument of flight than a small wing, without reference to the weight of the bird to be supported.

During the beat of the wings there is a certain forward and backward, as well as up and down, motion, so that the wing tip describes

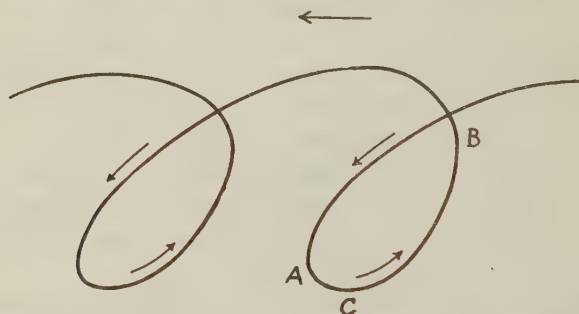


FIG. 1.—Theoretical trajectory of the wing tip, on a somewhat shortened horizontal scale

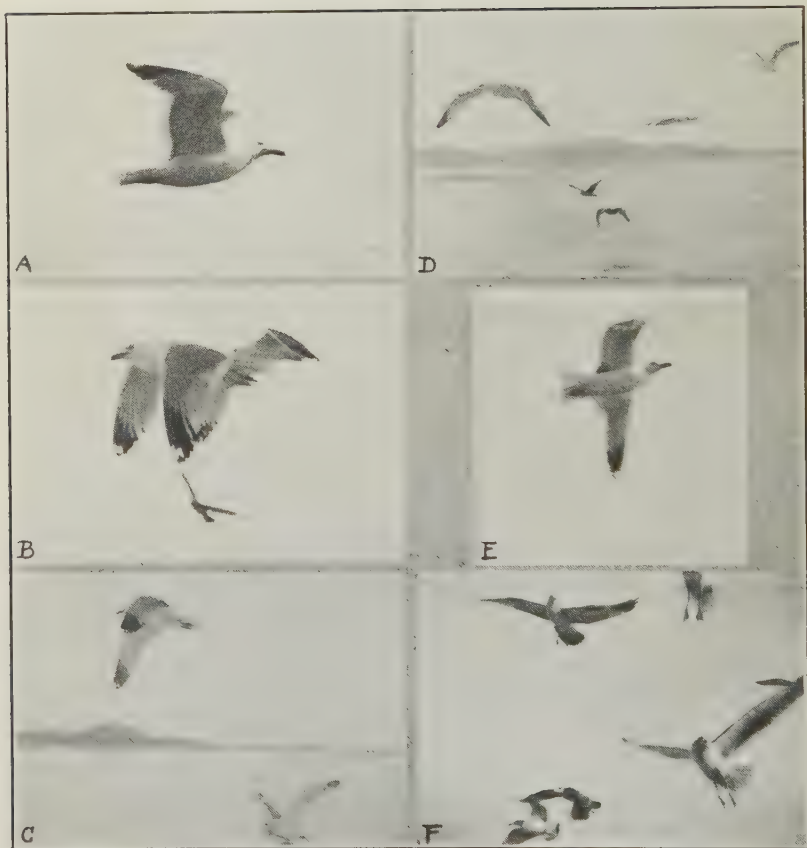
an ellipse with reference to the body of the bird, or, owing to the forward movement of the bird, a series of loops (fig. 1), which become more and more nearly closed with increasing acceleration of flight. It is possible even that the trajectory of the wing tip is a sort of figure 8, as Pettigrew (1847, pp. 15ff.) has insisted, and Marey (1890, p. 140) has described for the crow; but the presence of a secondary loop can not be determined by observation, and seems rather doubtful.

Two phases of the loop described by the wing are to be seen in Plate 2, C. The upper bird shows the wings advanced on the down stroke (position A, fig. 1), while the lower bird has them retired on the up stroke (position B, fig. 1). Plate 2, B, shows the wings with the front margins almost vertical, as they would appear at position C, Figure 1.

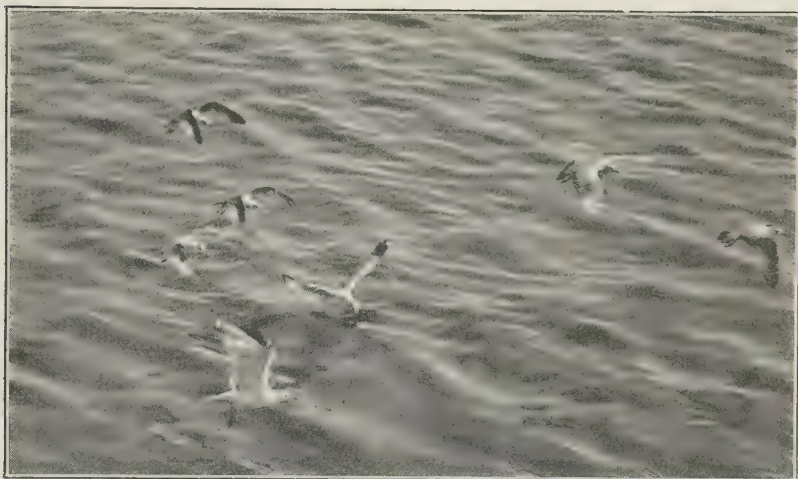
The effect of advancing the wings farther than normal is to rotate the front margins upward, so that the ventral surface is directed anteriorly, thus retarding forward flight. This is well shown in



CALIFORNIA GULLS IN SOARING FLIGHT



- A. THE BEGINNING OF THE STROKE
B. THE COMPLETION OF THE STROKE
C. WINGS ADVANCED ON THE DOWNSTROKE (LEFT) AND RETIRED ON THE UPSTROKE (RIGHT)
D. FIVE DIFFERENT PHASES OF THE STROKE
E. RAPID MOVEMENT OF THE WING TIP
F. THE USE OF FEET AND TAIL FOR RETARDING FLIGHT



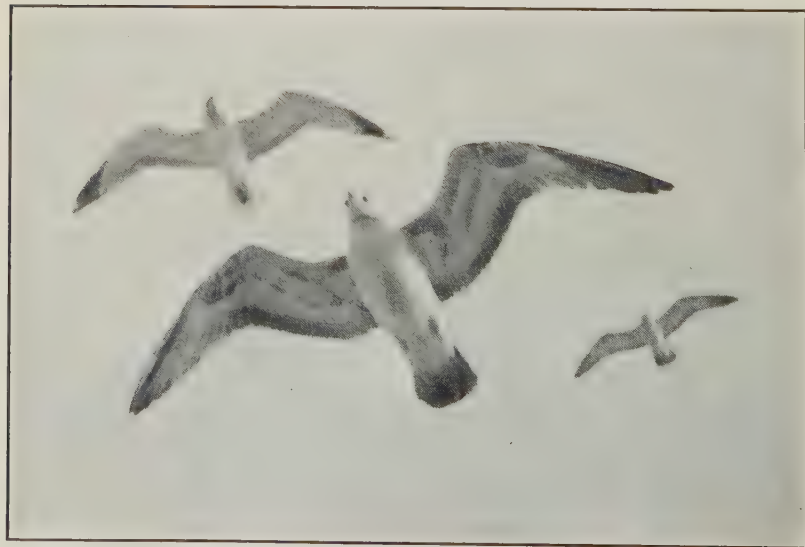
1. HOVERING OVER THE WATER WITH ALMOST NO FORWARD MOVEMENT.
NOTE ADVANCED POSITION OF THE WINGS



2. RISING FROM THE WATER. OBSERVE POSITIONS OF FEET



I. TYPICAL SOARING POSITIONS



2. SHORTENING SAIL BY BENDING WINGS AT WRIST

Plate 3, Figure 1. These gulls were hovering with almost no forward motion, picking up bits of food from the water without alighting. The advanced wings, depressed tail, and lowered feet indicate the efforts to check forward flight.

The feet are ordinarily held close against the under tail coverts in flight (pl. 2, A, C, and E), but may be lowered and even the webs spread out to act as "brakes" in retarding flight. The coordinated use of feet and tail for this purpose is admirably shown in Plate 2, F, especially in the bird only partly included at the top of the photograph.

In rising from the water a further use of the feet becomes evident (pl. 3, fig. 2). A certain forward momentum is necessary before the bird can rise, and a gull may often be seen contributing to the efforts of its wings by kicking vigorously as it leaves the water.

However complicated may be the process of flapping flight, so long as a bird's wings are in motion we are able to understand, at least in a measure, how it keeps aloft; but what are we to say when we witness a large bird sailing for great distances on almost motionless pinions without loss of altitude, or even steadily gaining altitude with no more effort than the occasional twitch of a wing in making an adjustment to some sudden gust? This is the phenomenon referred to as *soaring flight*, which has ever been a source of wonderment to layman and scientist alike.

While the gulls are not masters of this type of aerial navigation to quite the same extent as the larger hawks and vultures, nevertheless they often give remarkable exhibitions of their powers along this line. It is a common sight to observe a gull travel several miles at a speed of from 12 to 18 knots per hour without a single flap of the wings; and I think it probable that much higher speeds than this would be recorded if there were faster steamers on the bay to serve as a basis of comparison.

Various theories have been proposed from time to time to account for soaring flight, some of which are plausible, while others are rather obviously at variance with the facts.

It has been commonly urged that a soaring bird has gotten into an upward current of air, in which it has only to maintain itself by proper adjustments, retaining its height or ascending according to the force of the rising current and the angle of its wings. In other words, soaring flight is simply a downward glide in an ascending column of air.

It has been objected to this that birds are often seen to soar in the absence of any ascending current, so far as can be detected, and even that they studiously avoid such currents (Hankin, 1913, pp. 19, 63, etc.).

Lilienthal (1911, p. 78) advanced the somewhat surprising theory that the general trend of the wind everywhere is upward at an angle 3° to 4° to the horizon. The logical difficulties of such a theory are rather obvious, as at this rate we should shortly be living in a vacuum; and Headley (1895, p. 238) has comfortably demonstrated that the direction of a wind over a level plain is horizontal, although a very slight obstruction may cause a pronounced upward draft.

Opponents of the ascending current theory have proposed numerous other, and often less adequate, hypotheses to account for soaring flight.

Some have postulated a wavelike or pulslike motion of the air; according to this theory, the bird gains momentum by gliding with the wind in the interim between gusts, and gains altitude by turning to face each freshening breeze (Headley, 1895, p. 246). Others have maintained that small eddies or whirlpools in the air are taken advantage of, the bird meeting them and gaining energy by extinguishing their motion (Hankin, 1913, p. 62). A few have even urged that soaring flight is an illusion, the wings really being in motion, slight, but sufficient to keep the bird aloft. This rather strained hypothesis has probably been suggested by the occasional balancing movements which soaring birds are seen to make.

In the *American Naturalist* for 1886 we find a very remarkable theory advanced by I. Lancaster, which, stated briefly, is this: A properly constructed glider will move in a horizontal direction much more rapidly than it descends vertically. The more the wings are inclined, the greater becomes the horizontal motion relative to the vertical. If the wings are sufficiently inclined, as he assumes to be the case in the soaring bird, theoretically (?) the vertical motion should entirely cease, the pull of gravity causing only horizontal motion. This seems to be a roundabout way of stating that a soaring bird is really held up by the force of gravity!

A curious consequence of this theory was that Professor Hendricks (1886) thought it necessary to reply in a subsequent issue of the same journal with several pages of complicated mathematical disproof, demonstrating by various formulæ that the effect of gravity would actually be, not to support a soaring bird, but rather to bring it to earth!

A more recent investigator (Hankin, 1913) has discarded all theories having a basis in any known physical laws, and insists, on the grounds, be it said, of much excellent observation, that soaring flight must be referred to some entirely unknown quality of the atmosphere, which he terms "soarability." Of this he postulates two kinds, "sun soarability" and "wind soarability." Neither of

these depends upon ascending currents, but rather upon some mysterious transfer of sun (pp. 98, 105, 206) or wind (pp. 278 ff.) "energy" to the soaring bird. Such a theory can hardly be looked upon as doing aught but removing the phenomenon from the realm of possible explanation to that of pure mystery.

It seems at present that the earliest and simplest of these theories, that of ascending currents, is the most plausible. So far as the writer has been able to observe, it is entirely adequate to explain the soaring of gulls. The following extracts from my notes will indicate the basis of this statement:

August 17, 2.20 p. m.—Clear, bright day; stiff west wind. Several gulls observed sporting in current of air deflected upward by ferry slip at Oakland Mole. Would glide west some yards on motionless wings, gradually losing altitude, then rotate wings so as to be caught by breeze and swept back into ascending current, in which they would speedily rise with no visible effort and repeat the performance. This continued about five minutes, until birds were disturbed by coming of a boat.

August 13, 5.30 p. m.—Stiff west wind; several gulls soaring a few yards above and slightly to the leeward of the highest point on Goat Island.

July 29, 10.50 a. m.—Ferry traveling against stiff west wind. Gulls observed at points S, XX, and Y (fig. 2). Those at XX flapped continually. Those at Y took a zig-zag course, alternately flapping and sailing; they would gain momentum by flapping vigorously while in the shelter of the stern, then dive to one side into the wind and sail a moment, quickly losing momentum but gaining altitude. Then, from this increased height, they would dive back into the shelter of the stern, usually adding to their momentum by flapping, and continued across into the wind on the other side, where they would again gain altitude with the loss of momentum. This was repeated indefinitely, like a sort of play.

Several gulls were soaring without effort just above the forward pilot house. There was scarcely a visible wing movement so long as they remained in the area S (upward draft from bow), but they had to resort to flapping whenever they drifted to one side or the other of this area. (On several occasions a gull has been observed very distinctly to *fall off* this upward current, and drop suddenly somewhat laterally for 10 or 15 feet before righting itself.

July 30, 11.40 a. m.—Ferry going west against light breeze. Three gulls soared smoothly just above forward pilot house, balancing by occasional flick of wing tips.

7.30 p. m.—Ferry going east, with light wind from stern. Several gulls followed, flapping, at a distance. No soaring was attempted.

August 1, 3.20 p. m.—Ferry going west against very stiff wind. Very little soaring attempted, and only for a few moments at a time. One bird, alternately flapping and sailing, was caught by a sudden gust, almost capsized, and turned

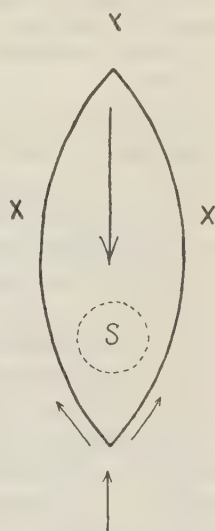


FIG. 2.—Diagram of positions of gulls about a ferry boat moving against the wind

completely around. In two or three seconds it righted and began following boat again.

November 6, 2.30 p. m.—Ferry going west; fair wind from starboard. A number of gulls soared over windward side, moving sidewise and forward, with left wing advanced (pl. 4, figs. 1 and 2); that is, the birds were moving with the boat, while facing a point halfway between the course of the boat and the direction of the wind.

3.40 p. m.—Ferry going east; wind from port. Birds soared as before, on windward side, but with right wing advanced, as would be expected from reversed direction of flight.

Their method of soaring was carefully observed. They would rise in the upward current at windward side until at a considerable height, then drift forward and laterally, to right or left, with gradual loss of altitude, until they circled back into the ascending current and rose again. Thus their flight was a series of circlings in and out of the ascending column of air, with a steady forward glide to keep pace with the boat. The wings were held nearly motionless, and slightly flexed (pl. 1) to derive the maximum lifting power of the wind.

The chronological order of these excerpts has been intentionally disturbed, in order that they may furnish illustrations respectively of the following points:

1. That gulls take advantage of the air currents deflected upward from buildings, steamers, hillsides, etc., to indulge in soaring flight.
2. That they have not been observed to soar in the absence of such currents.
3. That the most favorable conditions for soaring about a steamer occur with a moderately brisk wind from the bow, or either side.
4. That a very stiff wind is not favorable to soaring.
5. That the "soarable" position varies with the direction and speed of the wind, and the nature of the object causing the upward draft. Thus, in a moderate wind from starboard, the gulls soared over the windward side of the boat, while in a stiff breeze over the crest of Goat Island they soared to the leeward of the island. It has been observed also that, with increasing briskness of the wind about the ferryboats, the soarable area tends to move more and more to the leeward. This may explain the confusion which has existed upon the point (Hankin, 1913, p. 253), some observers reporting that gulls soar on the windward, others that they soar on the leeward side of steamers.

In conclusion it should be stated that these data are not intended to furnish an adequate explanation of soaring flight in general, but only of that of the gulls as I have observed it. It is entirely possible that, in the magnificent soaring of eagles and vultures, particularly as seen in the tropics, other factors may enter. Conditions at a height of 1 or 2 miles must be very different from what they are at the relatively small heights to which gulls attain.

But if, as some maintain, birds are able to soar in the absence of any *noticeable* upward movement of the air, it is yet entirely pos-

sible that such currents may be in operation, due to convection or other causes of atmospheric disturbance with which aeronauts are unpleasantly familiar. The wing of a bird, particularly of a large bird, is, as we have shown above, an extremely efficient instrument, capable of immediate adjustment to derive the maximum advantage from every movement of the air, so that a very slight upward draft may yield it considerable lift.

In any case, it seems wiser to go as far as we can with explanations in terms of known physical laws, rather than to postulate forces of which we know nothing, and which, if they exist, we have little chance of discovering.

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INSECT MUSICIANS, THEIR MUSIC, AND THEIR INSTRUMENTS

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THE SEASON'S PROGRAM

There is something peculiarly quiet about the evenings of spring and early summer in any country place sufficiently removed from the highways of human traffic, and from frog ponds. Robins may be warbling fragments of their song, or more commonly uttering that loud clatter with which they accompany their short flights from place to place, a song sparrow in the distance sings his bedtime melodies, a catbird is mewling from the hedge, a thrasher practices a few of his borrowed notes, a nighthawk makes a sudden swoop from overhead. As the shadows deepen, however, and the line of distant trees fades against the sobering sky, bird voices cease and the darkness brings silence, silence broken only at times by the song of some irrepressible mocker that continues his effervescence to uncertain hours, by the hoot of an owl, or by that long trill of the chipping sparrow which occasionally, in moonlight, rises at dead of night from somewhere in the fantastic, hazy distance.

But, on one of those first warm evenings toward the end of May, when the air is motionless though not yet sultry in southern Maryland, as the sun's fiery tints on the fleecy lining of sky give way to the paler tones of moonlight, there comes from somewhere on the lawn the first heralding of that troupe of insect choristers that later will make the night air ring from dusk to dawn with the strident music of their serenades. The announcement is a cheerful *chirp*, *chirp*, *chirp*, strong and clear but vibratory, the unmistakable notes of Gryllus, the common black cricket. These early arrivals belong to a group just now maturing that hatched the preceeding summer and wintered in a half-grown stage. For a month or more their vigorous chirps are heard in town and country, and then again there is silence, an interlude before the regular concert begins.

The season advances, the hot nights of July arrive, thunderstorms come and go, each leaving in its wake that oppressive evening

stillness reeking with moisture. On such a night, perhaps, toward the middle of July, as you may be meditating on nature's mightier forces, suddenly, from a near-by tree or shrub, you hear a voice, or the semblance of one, which says: *treat, treat, treat, treat*, regular repetitions of the one note 140 times a minute. Over there it is echoed by another, and over yonder by another. The next night still more join in, and soon the very atmosphere vibrates to that monotonously measured beat. This is the music of the snowy tree cricket, first of the summer chorus to arrive upon the stage.

A few nights later another sound cuts across the rhythmic concert, a longer, purring note, sad and melancholy in tone as if from some complaining spirit of the night, a soft *burr-r-r*, prolonged about two seconds and repeated at intervals of equal length. This is the song of the narrow-winged tree cricket, a cousin of the snowy. Representatives of his species likewise come on in greater numbers every evening till soon the nightly chorus is a blend of *treats* and *burrs*.

Then, to add to the confusion, several other bands arrive that strike up long unbroken trills, continued for many seconds or several minutes and immediately begun again. The chorus of the snowy and the narrow-winged now falls into the background and individual voices are lost as the entire concert becomes a ringing and shrilling arising at twilight, increasing with darkness, so invisibly linked with the oncoming shadows that it seems almost to be an emanation from the night itself. The trillers are also tree crickets, relations of the snowy and the narrow-winged, all members of the genus called *Oecanthus*. One of them is distinguished as the black-horned or striped tree cricket, another as the four-spotted, and a third as the broad-winged. The last is the loudest singer of them all.

As the hot weather waxes and the steamy nights of midsummer close in, some evening there will be heard from the lower branches of a tree just outside the door or from the vines about the porch a sharp *tzeet, tzeet, tzeet*, shrill notes quickly repeated perhaps a dozen times in succession but less rapidly and less sharply toward the end of the series. This is the song of the angular-winged katydid, not the true katydid, not that great singer of the forests, but a relation of his of larger stature, though of lesser talent.

Along with the angular-winged katydids come other members of the katydid family. Amongst them are the coneheads, sharp-headed, grasshopperlike insects, one of which, common in Maryland, makes a long continuous whirr of a very shrill tone and in a key so high that some human ears are not attuned to hear it at its highest pitch. Another utters a series of little notes like *tic, tic, tic*, repeated indefinitely. There is also another who is one of the noisiest of all American insect singers, his song being an extremely loud, shrill buzz of such volume that it can be heard from long distances. But this artist is so partial

to sandy fields near the seacoast that he is seldom heard by inland audiences. Most of the other actors on the stage at this season sing in tones so modest and subdued that their notes are generally lost in the all-pervading din of the crickets and other louder voiced performers. All save one, and this one is that star of the insect opera, the famous katydid.

To hear the true katydid you must ordinarily go to the deep woods, to the lonesome places of the night, for this virtuoso is no common dooryard singer. High in the oaks and hickories he dwells and there he and his troupe give their nightly serenades of *katy-did'*, *katy-did'*, *katy-she-did'*, and sometimes *katy-didn't*, a sound unmistakable and one never forgotten when once heard. The performance lasts all night and subsides only with the coming of dawn when insect concerts close.

About the middle of August, *Gryllus*, the black cricket, comes on the stage again, this time represented by more numerous individuals that hatched in spring from overwintering eggs. From now on his chirp is to be heard everywhere from lawn, garden, and field, both by day and by night, a sound always cheerful and always to be recognized by its vibratory quality. Associated with *Gryllus* is another smaller cricket of the turf, a very little fellow called *Nemobius*, with a very little voice, and one so delicate that you must bend low to catch his elfin notes, a silvery, twittering trill, rising like the music of some unseen pygmy from the grass.

Shortly after the advent of the second *Gryllus* band a new note breaks out, a loud, piping chirp inflected upward at the end, a sound easily mistaken for that of some little tree toad. The notes are hard to locate precisely, they seem to come from here, from there, from over yonder, and from back here again, but always singly. Their clear tones stand out distinctly above the general ring of mingled voices now at the peak of intensity, and, as nightly they become more numerous, they soon preempt the stage. They are the song of another cricket, the jumping bush cricket, more dignified by his scientific name of *Orocharis*.

Of course, the reader must understand that this program does not apply to all places alike. It is written for the neighborhood of Washington, D. C. *Orocharis*, for example, is abundant in Maryland but would be seldom heard in New England. Likewise, in New England the trilling tree crickets are less common, and consequently there the notes of the snowy and the narrow-winged have greater prominence. The katydids of New England also are less melodious than are those along the Potomac. In the South, especially in Florida, there are other singers that do not reach the latitude of Washington; while few of our common eastern favorites are to be heard in California.

But the insect musicians are not all minstrels of the night; there are daytime concerts, too, and the bill includes, besides the strictly daylight performers, some of the nocturnal singers. Gryllus, for example, sings at all hours, and the black-horned tree cricket makes the waysides ring with his shrill notes on warm bright afternoons of fall. Others of too little consequence to mention here will be described later. The great artist of the day is the cicada, an insect whose individuality sets him apart from all others. His song is that familiar, long, loud, buzzing hum which floats from the trees in undulous tones during the hot weather of August and September. Unfortunately, we commonly call the cicada a "locust," a name which properly belongs to the grasshoppers. The famous 17-year locust is a cicada that comes only periodically on the stage, but then often in vast numbers, and his grand concerts are notable events long remembered and discussed.

Orocharis is the last performer to appear on the nocturnal program. No other new notes after his are to be heard, though the voices of the others will change. As the cold of fall increases, the clear *treat, treat, treat* of the snowy cricket becomes a broken rattle, the sonorous purr of the narrow-winged changes to a long hoarse rasp, the notes of the trillers become weak and subdued, the cheerful chirps of Gryllus feeble and shaky, the notes of Orocharis dulled and tremulous. Yet on a cold wet night, such as those that so frequently mar the autumn season in southern New England, when the whole world seems blanketed in a dismal, cold, and penetrating mist, wetter than rain itself, it is marvelous to hear the insects still painfully proceeding with their concerts under circumstances that would stiffen the limbs and deaden the vital forces of many a stronger creature. The little tree crickets, themselves the very essence of frailty, not only keep their fires burning amidst their sodden environment, but still have emotions that must be expressed in song. And how gay and cheerful they seem again when the weather moderates, and how hopeful their voices sound on those last warm nights of fall. But at last the killing frosts arrive, insect voices are stilled, and the season's concert series ends.

The preceding is just a résumé of what there is to be heard on the insect stage day and night through the musical season. The concerts are all free and open to the public, but whoever would make acquaintance with the musicians themselves will find that this is not to be done by merely attending their performances, for conditions are quite different on the insect stage from what they are on our own. In the first place there is no conductor and all the artists, soloists and choristers alike, insist on coming on at the same time,

with a consequent medley of voices quite confusing to the uninformed listener. Then, too, the daylight performers usually sing from behind the scenes, while the stage at night is never illuminated, except by natural moonlight. Finally, the actors are bashful, avoid publicity, and most of them refuse to perform in limelight—interesting data for the student of comparative psychology. But there are no reserved seats in the theater, and the front rows are never crowded, consequently any interested member of the audience, by using sufficient caution, may get close enough to an individual singer to throw on him a quick flash from a lantern and catch a glimpse of him as he performs. Furthermore, with a little dexterity, the artist may be caught uninjured in a jar and taken home. If treated well, given leaves or whatever food he requires, and especially fresh drinking water every morning in the form of artificial dew made by sprinkling water on the foliage in his cage, the captive soon becomes accustomed to human surroundings and will often give private rehearsals, even sometimes in the glare of electric lights.

The rest of this paper is occupied mostly with the characteristics and personalities of our best known American insect singers, those of the eastern half of the Northern States. They all belong to four families, three being families of the order Orthoptera, including the grasshoppers, the katydids, and the crickets, and the other a family of the order Hemiptera, or sucking insects, which comprises the cicadas. The great majority of insects do not make any sounds at all audible to our ears. A few besides those just mentioned, such as some beetles, certain ants, and the queen bee produce squeaking or rasping sounds of various sorts, but they are seldom noted by human observers other than professional entomologists.

The reader may find interesting accounts of the habits and songs of American Orthoptera in the works of Allard, Blatchley, McNeill, Parrott and Fulton, Piers, Rehn and Heberd, Scudder, Somes, Walker, and others. But the numerous papers by these writers are scattered through many entomological publications, and the student will obtain easiest reference to all of them and abstracts from most of them, as well as almost all that is known of our eastern grasshoppers, katydids, crickets, and their relations in Blatchley's Orthoptera of Northeastern America. Scudder has given interpretations of the songs of the Orthoptera expressed in conventional musical notation, but the present writer knows nothing of the technique of music and can present the insect notes only by the usual approximate phonetic translations.

The critical reader has probably already made note of some mixing of metaphors. Therefore, before going further, it must be

clearly stated that *insects really do not sing*; that is, not if the verb "to sing" is to be used to refer only to the production of sounds by the breath on vocal chords. *The music of insects is all instrumental*; but it has always been described as "singing," even by the best entomologists, and we shall not here discard a term so convenient, especially since the dictionaries allow its more liberal usage. If then it is permitted to refer to an insect's music as its "song," by the same license we may speak of its "voice," though no insect makes truly vocal sounds. Likewise the word "note" is commonly used in zoology to mean the sound produced by a bird or insect, and in such connection does not signify a note on a musical scale. In strictly technical writing, the sounds or notes made by insects are called *stridulations*, from the Latin word *stridere*, meaning "to creak." They are made by special *stridulating organs*. These organs mostly correspond with the drum type of musical instruments in that they consist of membranes (tympana) or other broad surfaces that give forth sound by being set into rapid vibration. But there are two methods of producing the vibration, one by the rubbing of one surface on another, which may be likened to fiddling, and the other by the direct action of muscles attached to the vibratory surface, a method which has no counterpart in human organs or instruments. Finally, with very few exceptions, it is only the males among insects that sing or that have stridulating organs. This affords a suggestive theme for comparative comment, but it is one already too much dwelt upon by human writers, of the male sex, and we shall proceed now with the special descriptions of our musicians, their music, and their instruments.

THE GRASSHOPPER FAMILY

The grasshoppers belong to the family Acrididæ of the order Orthoptera. They are also designated the shorthorn grasshoppers to distinguish them from grasshopperlike members of the katydid family, or the longhorn grasshoppers, but they are more distinctively called locusts, though this name is applied mostly to certain migratory species. In the United States, however, the term "locust" has been given to the cicadas, resulting in much popular confusion of identities. For example, those destructive insects called locusts in the Bible are grasshoppers, related to our Rocky Mountain locust, but in no way related to the insects we commonly call the 17-year locusts, or to any other of the cicadas.

Not many of the grasshoppers are musical. They are mostly sedate creatures that conceal their sentiments if they have any; they are awake in the daytime and they sleep at night—commendable habits, but habits that seldom beget much in the way of artistic attainment.

Yet a few of the grasshoppers make sounds that are perhaps music in their own ears. One such is an unpretentious little brown species (fig. 1) about seven-eighths of an inch in length, marked by a large black spot on each side of the saddlelike shield that covers his back between the head and the wings. He has no other name than his scientific one of *Chloealtis conspersa*, for he is not widely known, since his music is of a very feeble sort. According to Scudder, his only notes resemble *tsikk-tsikk-tsikk*, repeated 10 or 12 times in about three seconds in the sun, but at a slightly slower rate in the shade. *Chloealtis* is a fiddler and plays two instruments at once. The fiddles are his front wings and the bows his hind legs. On the inner surface of each hind thigh or femur there is a row of minute teeth (fig. 1, B, *a*), shown more magnified at C. When the thighs are scraped over the edges of the wings their teeth scrape on a sharp-edged vein indi-

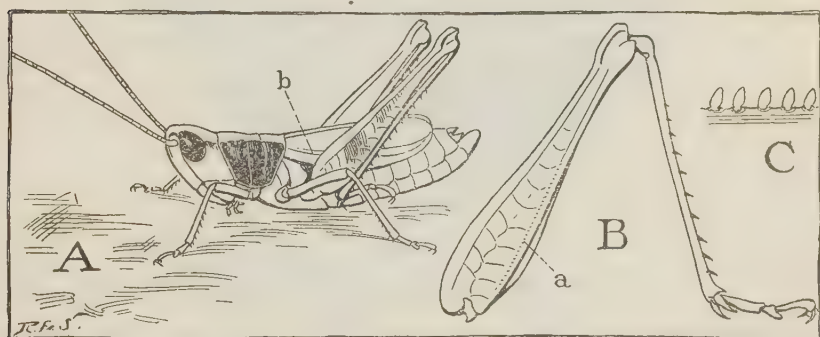


FIG. 1.—A grasshopper that makes a sound by scraping its toothed hind thigh over a sharp-edged vein (*b*) on the wing. (*Chloealtis conspersa*.) A, the male grasshopper (twice natural size), showing stridulating vein (*b*) of left wing. B, inner surface of right hind thigh, showing row of teeth at *a*. C, the teeth more enlarged

cated by *b*. This produces the *tsikk*-sound just mentioned. Such notes contain little music to us, but Scudder says he has seen three males singing to one female at the same time. This female, however, was busy laying her eggs in a near-by stump, and there is no evidence given to show that even she appreciated the efforts of her serenaders.

Several other little grasshoppers fiddle after the manner of *Chloealtis*; but another, *Mecostethus gracilis* by name (fig. 2), instead of having the rasping points on the legs, has on each fore wing one of the veins (B, *I*) and its branches provided with many small teeth, shown enlarged at C, upon which it scrapes a sharp ridge on the inner surface of the hind thigh.

In another group of grasshoppers there are certain species that make a noise as they fly, a crackling sound apparently produced in some way by the wings themselves. One of these, common through the Northern States, is known as the cracker locust, *Circotettix ver-*

ruculatus, on account of the loud snapping notes it emits. Several other members of the same genus are also cracklers, the noisiest being a western species called *C. carlingianus*. Scudder says he has had his attention drawn to this grasshopper "by its obstreperous crackle more than a quarter of a mile away. In the arid parts of the West it has a great fondness for rocky hillsides and the hot vicinity of abrupt cliffs in the full exposure to the sun, where its clattering rattle reechoes from the walls."

One of the commonest of our larger grasshoppers is the Carolina locust, *Dissosteira carolina*. Its exposed colors are mottled to match

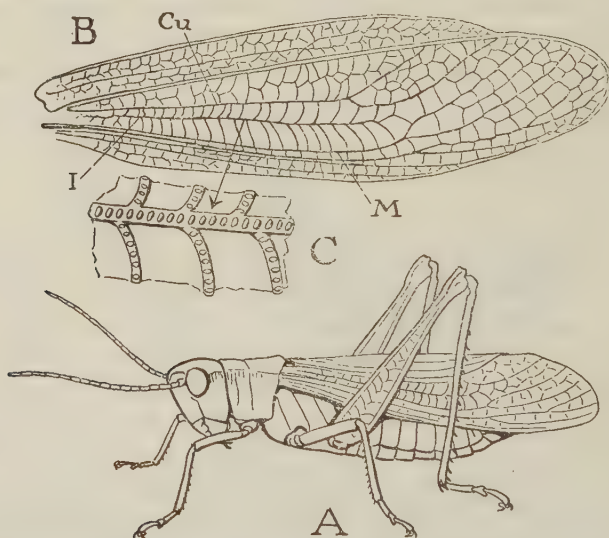


FIG. 2.—A grasshopper that makes a sound by scraping a sharp ridge on the inner surface of the hind thigh against a toothed vein on the wing. (*Mecostethus gracilis*.) A, the male grasshopper (twice natural size). B, left front wing; the toothed vein is the intercalary vein (*I*) and its branches, between the cubitus (*Cu*) and the media (*M*). C, part of intercalary vein and branches, more enlarged, showing rows of teeth

the tones of the ground, but when it flies it unfolds a striking display of black bordered with yellow on its fanlike hind wings (fig. 3). This locust is a strong flier and when flushed sails away in the air on an undulating course over the tops of weeds, over bushes, and sometimes over the tops of small trees, but always swerving this way and that as if undecided where to alight. At times it has a habit of hovering several feet up in the air over a certain spot on the ground and of making a subdued crackling with the wings.

Various observers have noted these hovering flights of the Carolina locust, performed always by the males as if they were holding some sort of a contest in aeronautics. Townsend, seeing a male alight on the ground after hovering for some time, noted in a few minutes

another male, "which had witnessed the performance at a short distance," fly quickly over and alight by the side of the first performer. He says, "they ran by each other several times, occasionally touching each other, but did not make any further manifestations, and finally the last one flew away, leaving the other motionless in the grass." Townsend thinks it probable that the females are attracted by these performances of the males, and that the males vie with one another in their exhibitions and are inclined to fight from a feeling of rivalry, the one that flies away having been beaten. He says "there is little doubt that in some instances the males actually clasp and fight" (though no instance is given), "but that more often one of them admits his defeat without recourse to blows." Finally, he concludes,



FIG. 3.—The Carolina locust, *Dissosteira carolina*, with wings spread, and in position at rest

"the females doubtless are in waiting in convenient spots, from which they witness these scenes, and ultimately accept the males whose superior intimidating powers have resulted in their being left in undisputed possession." This passage would be more convincing if it were not for that word "doubtless." On the other hand, Some, another observer of the hovering performances of the same locust, suggests that they are merely games of sport between the males, "possibly akin to the jumping contests of small boys." All of which shows how difficult it is for us to interpret the behavior of insects.

The grasshoppers have a pair of eardrumlike membranes sunken in large cavities on the sides of the body beneath the bases of the wings (fig. 32, *e*), which are supposed to be hearing organs, the detail structure of which will be described in the last section of this paper.

THE KATYDID FAMILY

While the grasshoppers give examples of the more primitive attempts of insects at musical production, and may be compared in this respect to the more primitive of human races, the katydids show the highest development of the art attained by insects. But, just as the accomplishments of one member of a human family may give prestige to all his relations and descendents, so the talent of one noted member of the katydid family has given notoriety to all his congeners, and his justly deserved name has come to be applied by the indiscriminating public to a whole tribe of singers of lesser or

very mediocre talent whose only claim to the name of katydid is that of family relationship.

In Europe the true katydid is unknown, and there his family is called simply the longhorn grasshoppers. In entomology the family is now the *Tettigoniidæ*, though it had long been known as the *Locustidæ*.

The katydids in general are most easily distinguished from the locusts or short-horn grasshoppers by the great length of their antennæ, those delicate, sensitive, tapering threads projecting from the forehead. But the two families differ also in the number of joints in their feet, the grasshoppers having three (fig. 4, A) and the katydids four (B). The grass-

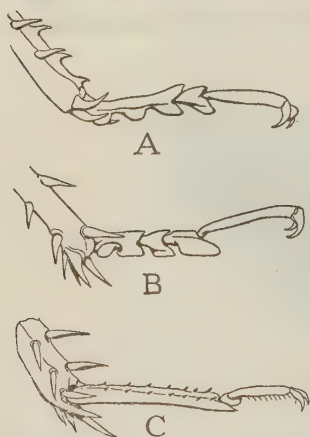


FIG. 4.—Distinctive characters in the feet of the three families of singing Orthoptera.

A, the hind foot of a grasshopper (*Dissosteira carolina*). B, the hind foot of a katydid (*Microcentrum rhombifolium*). C, the hind foot of a cricket (*Gryllus assimilis*)

hoppers place the entire foot on the ground, while the katydids ordinarily walk on the three basal segments only, carrying the long terminal joint elevated. The basal segments have pads on their under sides that adhere to any smooth surface such as that of a leaf, but the terminal joint bears a pair of claws, used when it is necessary to grasp the edge of a support. The katydids are mostly creatures of the night and, though usually plain green in color, many of them have elegant forms. Their attitudes and general comportment suggest much more refinement and a higher breeding than that of the heavy-bodied locusts. Though some members of the katydid family live in the fields and are very grasshopperlike or even cricketlike in form and manners, the characteristic species are seclusive inhabitants of shrubby or trees. These are the true aristocrats of the Orthoptera.

The musical instruments of the katydids are quite different from those of the grasshoppers, being situated on the overlapping bases of the front wings or tegmina. On this account the front wings of the males are always different from those of the females, the latter retaining the usual or primitive structure. The right wing of a female of one of the more grasshopperlike species, *Orchelimum laticauda* (fig. 16), is shown at C of Figure 5. The wing is traversed by four principal veins springing from the base. The one nearest the inner edge is called the cubitus (*Cu*) and the space between it and this margin of the wing is filled with a network of small veins having no particular arrangement. In the wings of the male, however, shown at A of the same figure, this inner basal field is much enlarged and consists of a thin, crisp membrane (*Tm*), braced by a number of veins branching from the cubitus (*Cu*). One of these (*fv*), running crosswise through the membrane, is very thick on the left wing, and when the wing is turned over (*B*) it is seen to have a close series of small cross ridges on its under surface which convert it into a veritable file (*f*). On the right wing this same vein is much

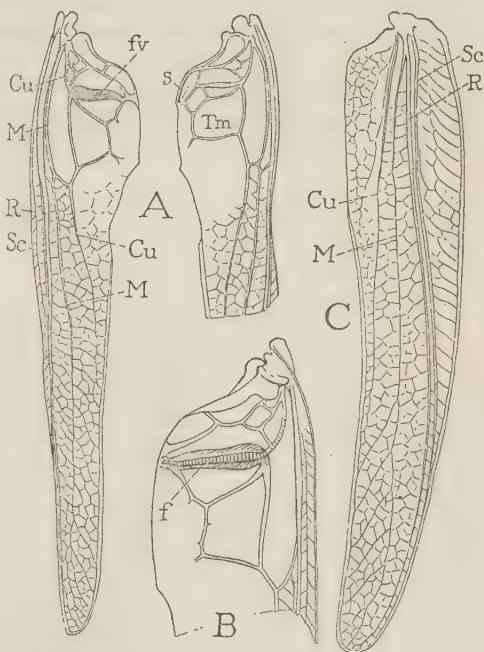


FIG. 5.—The front wings or tegmina of a meadow grasshopper (*Orchelimum laticauda*), illustrating the sound-making organs typical of the katydid family. A, left front wing and basal part of right wing of male, showing the four main veins, subcosta (*Sc*), radius (*R*), media (*M*), and cubitus (*Cu*), also the enlarged basal, vibrating area or tympanum (*Tm*) of each wing, the thick file vein (*fv*) on the left, and the scraper (*s*) on the right. B, lower surface of base of left wing of male, showing the file (*f*) on under side of the file vein (*A, fv*). C, right front wing of female, which has no sound-making organs, showing simple, normal venation.

more slender and its file is very weak, but on the basal angle of this wing there is a stiff ridge (*s*) not developed on the other. The katydids always fold the wings with the *left overlapping the right*, and in this position the file of the former lies above the ridge (*s*) of the latter. If now the wings are moved sideways, the *file* grating on the ridge or *scraper* causes a rasping sound, and this is the way the katydid makes the notes of its music. The tone and

volume of the sound, however, are probably in large part due to the vibration of the thin basal membranes of the wings, which are called the tympana (*Tm*).

The instruments of different players differ somewhat in the details of their structure. There are variations in the form and size of the file and the scraper on the wings of different species, and differences in the veins supporting the tympanal areas, as shown in the drawings of these parts from a conehead (fig. 13) given at A, B,

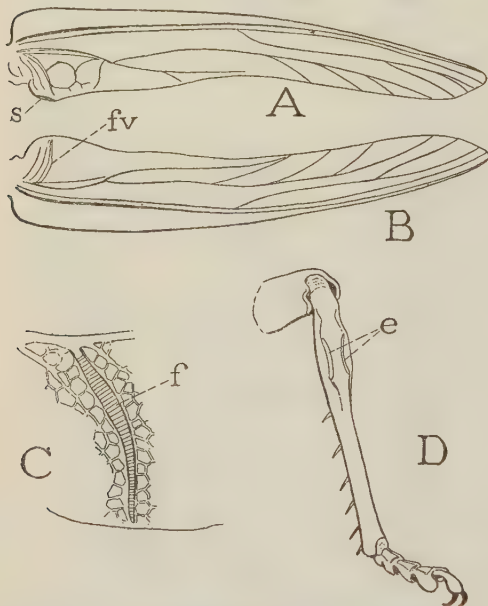


FIG. 6.—Sound-making organs and the "ears" of a conehead grasshopper (*Neoconocephalus ensiger*), another member of the katydid family. A, B, right and left front wings, showing the scraper (*s*) on the right wing and the file vein (*fv*) on the left. C, under surface of file vein, showing the file (*f*). D, front leg, showing the slits (*e*) opening into pockets containing the "ears." (See fig. 35, A)

and C, of Figure 6. In the true katydid, the greatest singer of the family, the file, the scraper, the tympana, and the wings themselves (fig. 12) are all very highly developed to form an instrument of great efficiency. But, in general, the instruments of different species do not differ nearly so much as do the notes produced from them by their owners. An endless number of tunes may be played upon the same fiddle. With the insects each musician knows only one tune, or a few simple variations of it, and this he inherited from his ancestors along with a knowledge of how to play it on his inherited instrument. The stridulating organs are not functionally developed

until maturity, and then the insect forthwith plays his native air. He never disturbed the neighbors with doleful notes by practicing.

Very curiously none of the katydids nor any members of their family have the earlike organs on the sides of the body possessed by the locusts. What are commonly supposed to be their organs of hearing are located in their front legs, as are the similar organs of the crickets. Two vertical slits on the upper parts of the shins or tibiae (fig. 6, D, *e*) open each into a small pocket with a tympanum-like membrane stretched across its inner wall. Between the membranes are air tubes and other structures, to be described later along

with the "ears" of the grasshopper. No one can state positively that any of these organs are ears, the principal reasoning in favor of their auditory nature being "if they are not ears, what are they?"

THE ROUND-HEADED KATYDIDS

The members of this first group of the katydid family are characterized by having large wings and a smooth round forehead. They compose the subfamily Phaneropterinæ, which includes species that attain the acme of grace, elegance, and refinement to be found in the entire Orthopteran order. Nearly all of the round-headed katydids are musical to some degree, but their productions are not of a

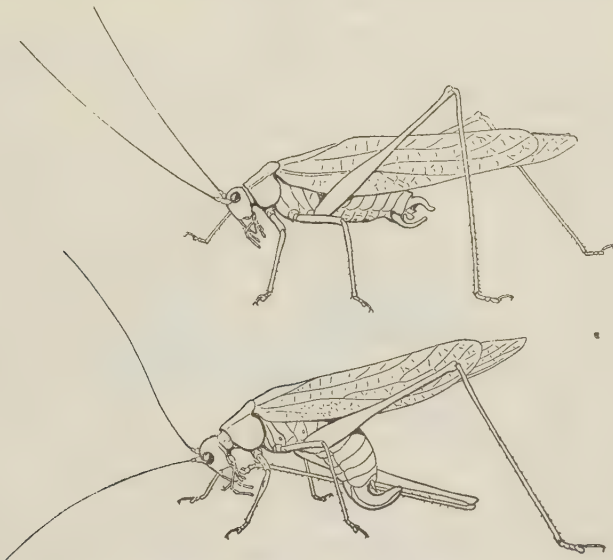


FIG. 7.—A bush katydid (*Scudderia furcata*). Upper figure a male; lower a female in act of cleaning a hind foot

high order. On the other hand, though their notes are in a high key, they are usually not loud and not of the kind that keep you awake at night.

Amongst this group are the bush katydids, species of medium size with slenderer wings than the others, comprised in the genus usually known as *Scudderia* but also called *Phaneroptera*. They have acquired the name of bush katydids because they are usually found on low shrubbery, particularly along the edges of moist meadows, though they inhabit other places too and their notes are often heard at night about the house. Our commonest species, and one that occurs over most of the United States, is the fork-tailed bush katydid (*Scudderia furcata*). Figure 7 shows a male and a female, the female in the act of cleaning the pads on one of her hind feet.

The katydids are all very particular about keeping their feet clean, for it is quite necessary to have their adhesive pads always in perfect working order, but they are so continually stopping whatever they may be doing to lick one foot or another, like a dog scratching fleas, that it looks more like an ingrown habit with them than a necessary act of cleanliness. The fork-tailed katydid is a very unpretentious singer and has only one note, a high pitched *zeep* reiterated several times in succession. But it does not repeat the series continuously as most other singers do, and its music is likely to be lost to human ears in the general din from the jazzing bands of crickets. Yet occasionally its soft *zeep, zeep, zeep* may be heard from a near-by bush or from the lower branches of a tree.



FIG. 8.—The oblong-winged katydid, *Amblycorypha oblongifolia*, male

The notes of other species have been described as *zikk, zikk, zikk*, or *zeet, zeet, zeet*, and some observers have recorded two notes for the same species. Thus Scudder says that the day notes and the night notes of *Scudderia curvicauda* differ considerably, the day note being represented by *bzrwi*, the night note, which is only half as long as the other, by *tchw*. (With a little practice the reader should be able to give a good imitation of this katydid.) Scudder furthermore says that they change from the day note to the night note when a cloud passes over the sun as they are singing by day.

The genus *Amblycorypha* includes a group of species having wider wings than those of the bush katydids. Most of them are indifferent singers; but one, the oblong-winged katydid (*A. oblongifolia*), found over all the eastern half of the United States and southern

Canada, is noted for its large size and dignified manners. A male (fig. 8), kept by the writer one summer in a cage, never once lost his decorum by the humiliation of confinement. He lived apparently a natural and contented life, feeding on grape leaves and on ripe grapes, obtaining the pulp of the latter by gnawing holes through the skin. He was always sedate, always composed, his motions always slow and deliberate. In walking he carefully lifted each foot and brought the leg forward with a steady movement to the new position, where the foot was carefully set down again. Only in the act of jumping did he ever make a quick movement of any sort. But his preparations for the leap were as calm and unhurried as his other acts: Pointing the head upward, dipping the abdomen slowly downward, the two long hind legs bending up in a sharp inverted V on each side of the body, one would think he was deliberately preparing to sit down on a tack, but all at once a catch seems to be released somewhere as he suddenly springs upward into the leaves overhead, at which he had taking such long and careful aim.

For a long time the aristocratic prisoner uttered no sound, but at last one evening he repeated three times a squeaking note resembling *shriek* with the *s* much aspirated and with a prolonged vibration on the *ie*. The next evening he played again, making at first a weak *swish*, *swish*, *swish*, with the *s* very sibilant and the *i* very vibratory. But after giving this as a prelude he began a shrill *shrie-e-e-e-k*, *shrie-e-e-e-k*, repeated about six times, a loud sound described by Blatchley as a "creaking squawk—like the noise made by drawing a fine-toothed comb over a taut string."

The best known members of the round-headed katydids, and perhaps of the whole family, are the angular-winged katydids (fig. 9). These are large, maple-leaf green insects, much flattened from side to side, with the leaflike wings folded high over the back and abruptly bent on their upper margins, giving the creatures the hump-backed appearance from which they get their name of angular-winged katydids. The sloping surface of the back in front of the hump makes a large flat triangle, plain in the female, but in the male corrugated and roughened by the veins of the musical apparatus.

There are two species of the angular-winged katydids in the United States, both belonging to the genus *Microcentrum*, one distinguished as the larger angular-winged katydid, *M. rhombifolium*, and the other as the smaller angular-winged katydid, *M. retinerve*. The females of the larger species (fig. 9), which is the more common one, reach a length of $2\frac{3}{8}$ inches measured to the tips of the wings. They lay flat, oval eggs, stuck in rows overlapping like scales along the surface of some twig or on the edge of a leaf.

These katydids are attracted to lights and may frequently be found on warm summer nights in the shrubbery about the house,

or even on the porch and the screen doors. They usually make their presence known by their soft but high-pitched notes resembling *tzeet* uttered in short series, the first notes repeated rapidly, the others successively more slowly as the tone becomes also less sharp and piercing. This is the song of the larger species and may be



FIG. 9.—The larger angular-winged katydid, *Microcentrum rhombifolium* (one-fourth larger than natural size). Upper, a male; lower, a female

written *tzeet-tzeet-tzeet-tzek-tzek-tzek-tzuk-tzuk*, though the high key and shrill tones of the notes must be imagined. Riley describes the song as a series of raspings "as of a stiff quill drawn across a coarse file," and Allard says the notes "are sharp, snapping crepitations and sound like the slow snapping of the teeth of a stiff comb as some object is slowly drawn across it." He represents

them thus: *tek-ek-ek-ek-ek-ek-ek-ek-ek-ek-ek-tzip*. But, however the song of *Microcentrum* is to be translated into English, it contains no suggestion of the notes of his famous cousin, the true katydid. Yet most people confuse the two species, or, rather, hearing the one and seeing the other, they draw the obvious conclusion that the one seen makes the sounds that are heard.

The angular-winged katydids are very gentle and unsuspicious creatures, allowing themselves to be picked up without any attempt at escaping. But they are good fliers, and when launched into the air sail about like miniature airplanes, with their large wings spread out straight on each side. When at rest they have a comical habit of leaning over sideways as if their tall, flat forms were top-heavy.

THE TRUE KATYDID

We now come to that artist who bears by right the name of "katydid," the insect (fig. 10) known to science as *Pterophylla*



FIG. 10.—The true katydid, *Pterophylla camellifolia*, male (one-fourth larger than natural size)

camellifolia, and to the American public as the greatest of insect singers. Whether the katydid is really a great musician or not, of course, depends upon the critic, but of his fame there can be no question, for his name is a household term as familiar as that of any of our own great artists, notwithstanding that there is no phonographic record of his music. To be sure, the cicada has more of a world-wide reputation than the katydid, for he has representatives in many lands, but he has not put his song into words the public can understand. And if simplicity be the test of true art, the song of the katydid stands the test, for nothing could be simpler than merely *katy-did*, or its easy variations, such as *katy*, *katy-she-did* and *katy-didn't*.

Yet though the music of the katydid is known by ear or by reputation to almost every native American, but few of us are acquainted

with the musician himself. This is because he almost invariably chooses the tops of the tallest trees for his stage and seldom descends from it. His lofty platform, moreover, is also his studio, his home,

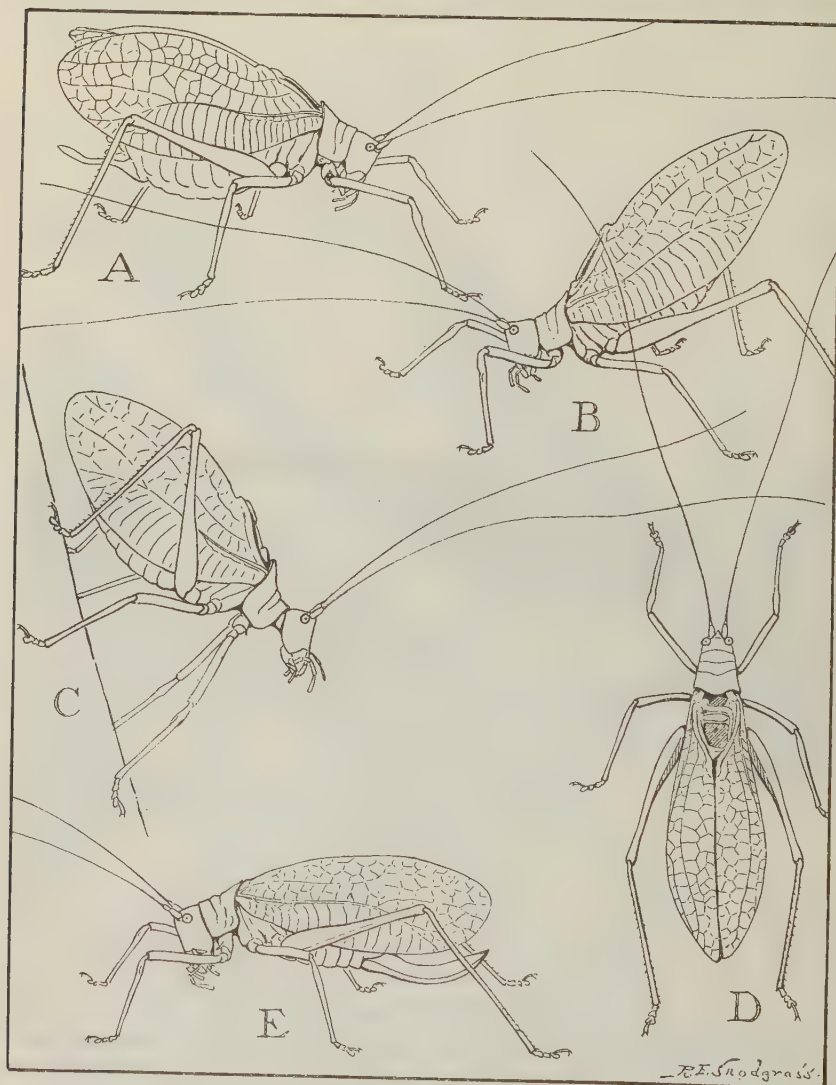


FIG. 11.—The katydid in various attitudes.

A, usual position of male while singing. B, attitude while running rapidly on a smooth surface. C, preparing to leap from a vertical surface. D, a male seen from above. E, a female showing the wide flat ovipositor

and his world, and the reporter who would have a personal interview must be efficient in tree climbing. Occasionally, though, it happens that a singer may be located in a smaller tree where access to him is easier or from which he may be dislodged by shaking. The writer

obtained one specimen, secured in this way on August 12, that lived till the 18th of October and furnished the following notes:

The physical characters of the captive and some of his attitudes are shown in Figures 10 and 11. His length is $1\frac{3}{4}$ inches from the forehead to the tips of the folded wings, the front legs are longer and thicker than in most other members of the family, while the hind legs are unusually short. The antennæ, though, are extremely long, slender and very delicate filaments, $2\frac{1}{8}$ inches in length. Between the bases of the antennæ on the forehead there is a small conical projection, a physical character which separates the true katydid from the round-headed katydids and assigns him to the subfamily called the Pseudophyllinæ, which includes, besides our species, many others that live mostly in the Tropics. The rear margins of the wings are evenly rounded and their sides strongly bulged outward as if to cover a very plump body, but the space between them is mostly empty and probably forms a resonance chamber to give tone and volume to the sound produced by the stridulating parts. What might be the katydid's waistcoat, the part of the body exposed beneath the wings, has a row of prominent buttonlike swellings along the middle which rhythmically heave and sink with each respiratory movement. All the katydids are deep, abdominal breathers.

The color of the katydid is plain green, with a conspicuous dark-brown triangle on the back covering the stridulating area of the wings. The tips of the mouth parts are yellowish. The eyes are of a pale transparent green, but each has a dark center that, like the pupil of a painting, is always fixed upon you from whatever angle you retreat.

The movements of the captive individual are slow, though in the open he can run rather rapidly, and when he is in a hurry he often takes the rather absurd attitude shown at B of Figure 11, with the head down and the wings and body elevated. He never flies and was never seen to spread his wings, but when making short leaps the wings are slightly fluttered. In preparing for a leap, if only one of a few inches or a foot, he makes very careful preparations, scrutinizing the proposed landing place long and closely, though perhaps he sees better in the dark and acts then with more agility. If the leap is to be made from a horizontal surface he slowly crouches with the legs drawn together, assuming an attitude more familiar in a cat; but if the jump is to be from a vertical support he raises on his long front legs as at C of Figure 11, suggesting a camel browsing on the leaves of a tree. He sparingly eats leaves of oak and maple supplied to him in his cage, but appears to prefer fresh fruit and grapes and relishes bread soaked in water. He drinks rather less than most Orthopterans.

When the katydids are singing at night in the woods they appear to be most wary of disturbance, and often the voice of a person approaching or a crackle under foot is sufficient to quiet a singer far overhead. The male in the cage never utters a note until he has been in darkness and quietness for a considerable time. But when he seems to be assured of solitude he starts his music, a sound of tremendous volume in a room, the tones incredibly harsh and rasping at close range, lacking entirely that melody they acquire with space and distance. It is only by extreme caution that the performer may be approached while singing, and even then the brief flash of a light is usually enough to silence those stentorian notes. Yet occasionally a glimpse may be had of the musician as he plays, most frequently standing head downward, the body braced rather stiffly on the legs, the front wings only slightly elevated, the tips of the hind wings

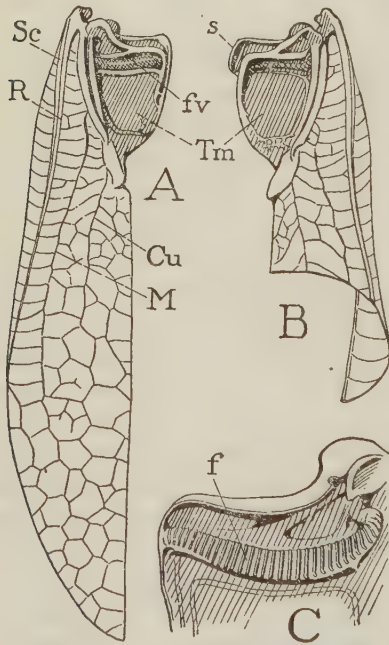


FIG. 12.—Wings and sound-making organs of the male katydid. A, left front wing showing the greatly enlarged tympanal area (*Tm*) with its thick file vein (*fv*). B, base of right wing with large scraper (*s*) on its inner angle, but with very small file vein. C, under surface of file vein of left wing, showing large, flat, coarse file (*f*)

projecting a little from between them, the abdomen depressed and breathing strongly, the long antennal threads waving about in all directions. Each syllable appears to be produced by a separate series of vibrations made by a rapid shuffling of the wings, the middle one being more hurried and the last more conclusively stressed, thus producing the sound so suggestive of *ka-ty-did'*, *ka-ty-did'*, which is repeated regularly about 60 times a minute on warm nights. Usually at the start and often for some time only two notes are uttered, *ka-ty*, as if the player has difficulty in falling at once into the full swing of *ka-ty-did*.

The structure of the wings and the details of the stridulating parts are shown in Figure 12. The wings (A, B) fold vertically against the sides of the body, but their inner basal parts form wide, stiff, horizontal, triangular flaps that overlap, the left on top of the right. A thick, sunken crosswise vein (*fv*) at the base of the left tympanum (*Tm*) is the file vein. It is shown from below at C where the broad, heavy file (*f*) is seen with

its row of extremely coarse rasping ridges. The same vein on the right wing (B) is much smaller and has no file, but the inner basal angle of the tympanum is produced into a large lobe bearing a strong scraper (*s*) on its margin.

The writer has listened to the katydids out of doors in Massachusetts, Connecticut, Maryland, Virginia, and Indiana. While the notes of the Hoosiers are not distinctly recalled, it is very noticeable that the song of the katydids about Washington is much less harsh and grating in tone than is that of the New Englanders. The katydids heard near Amherst, Mass., and near Wallingford, Conn., uttered always two syllables much more commonly than three, and the sounds can be represented only as a harsh *squă-wăk'*, *squă-wăk'*, *squă-wăk'*, the second syllable a little longer than the first. This is not the case with those that say *ka-ty*. When there are three syllables the series is *squă-wă-wăk'*. If all New England katydids sing thus it is not surprising that some New England writers have failed to see how the insects ever got the name of "katydid." Scudder says "their notes have a shocking lack of melody" and he represents the sound by *ar*. He attended a katydid concert at Springfield, Mass., and records that the song is usually of only two syllables: "that is," he says, "they rasp their fore wings twice rather than thrice; these two notes are of equal (and extraordinary) emphasis, the latter about one-quarter longer than the former; or if three notes are given, the first and second are alike and a little shorter than the last."

The katydids in the vicinity of Washington, D. C., certainly say "katy-did" as plainly as any insect could. Of course the sound is more literally to be represented as *kă ki-kăk'*, accented on the last syllable. When only two syllables are pronounced they are always the first two and the couplet sounds quite different from the squawking *squă-wăk'* of the New England katydids. Sometimes an individual in a band utters four syllables, "katy-she-did" or *kă ki-kă-kăk'*, and again a whole band is heard singing in four notes with only an occasional singer giving three. It is said that in certain parts of the South the katydid is called a "cackle-jack," a name which, it must be admitted, is a very literal translation of its notes, but one lacking in sentiment and unbecoming an artist of such repute.

When we listen to insects singing, the question always arises of why they do it, and we might as well admit that we do not know what motive impels them. It is probably an instinct with the males to use their stridulating organs, but in many cases the tones emitted are clearly modified by the physical or emotional state of the player. The music seems in some way to be connected with the mating of the sexes, and the usual idea is that the sounds are attractive to the females. With many of the crickets, however, the real attraction that

the male has for the female is a liquid exuded on his back, the song apparently being a mere advertisement of his wares. In any case the ecstasies of love and passion ascribed to male insects in connection with their music are probably more fanciful than real. The subject is an enchanted field where the scientist has most often weakened and wandered from the narrow path of observed facts, where he has indulged in a freedom of imagination comparable only with that of a newspaper reporter chronicling some event of the daily news. Thus Blatchley, in describing the singing and wooing of the katydids in Indiana, says:

"One idea alone possessed the minds of the male musicians. That idea was love passion—'that greatest thing in the universe.' Long and loud the cymbals sounded, each shuffle, each note, doubtless accompanied by the wish that the next would call from the skies, from the branches above or about them—from anywhere, it mattered not—one of their form and kind." The serenade, he further says, "continued almost unbroken from dark till dawn. A serenade it was in truth—a song of love—of passion, poured out in the listening ears of the other sex. At times a single player dropped out of the chorus. His work, his love calls had not been in vain. From some leafy retreat, where she had been hidden by day, a lady katydid slowly emerged, and, entranced by the song—by, to her ears, the tender wooing notes—drew nearer and nearer unto the charmed circle whence the cymbals clanged and shuffled. Their notes became less vigorous. More softly they fell upon the ear, until finally as she coyly advanced they ceased and the caresses of antennæ took their place."

The details in this report are too unconvincing and arouse suspicion that much of the very interesting performance took place in Mr. Blatchley's imagination as he "listened for hours" that August night in Indiana to the katydids' serenade. We must suspect that the balmy midnight air, a silvery moon perhaps, and the melodious "clang and shuffle" of the cymbals also produced effects, and that the next morning there were many things interwoven in the memory of the listener that crept into the pleasing story he recounts.

Or also we may read from Riley: "To the mind of the naturalist, trained in deciphering nature's hieroglyphics, the chattering song is very plainly inspired by love. The male katydid doubtless feels something of the same satisfaction in playing to his companions, and especially to Katy, as a prima donna does in singing to an audience. There is a pleasure in the act which is the outcome of its being; and the fact that the males are principally the players shows that the gift is not only a source of pleasure but one of much importance to the species; for the rivalry among the males is as great

as among higher animals, and a good instrument becomes, in this light, most important to the individual and to the species. The best player wins his coveted love, while the feeble and the cripples stand no chance to impair the vigor of the race." All such ideas need to be substantiated by more facts than are at hand at present on this interesting subject.

THE CONEHEADS

This group of the katydid family contains slender, grasshopper-like insects that have the forehead produced into a large cone and the face strongly receding, but which also possess long slender antennæ that distinguish them from the true or shorthorn grasshoppers. They constitute the subfamily Copiphorinæ.



FIG. 13.—A conehead grasshopper (*Neoconocephalus retusus*). Upper, a male; lower, a female, with extremely long ovipositor

One of the commonest and most widely distributed of the larger coneheads is the species known as *Neoconocephalus ensiger*, or the sword-bearing conehead. It is the female, however, that carries the sword; and it is not a sword either, but merely the immensely long egg-laying instrument properly called the ovipositor. The female conehead shown at B of Figure 13 has a similar organ, though she belongs to a species called *retusus*. The two species are very similar in all respects except for slight differences in the shape of the cone on the head. They look like slim, sharp-headed grasshoppers, $1\frac{1}{2}$ to $1\frac{3}{4}$ inches in length, usually bright green in color, though sometimes brown.

The song of *ensiger* sounds like the noise of a miniature sewing machine, consisting merely of a long series of one note, *tick, tick,*

tick, tick, etc., repeated indefinitely. Scudder says *ensiger* begins with a note like *brw*, then pauses an instant and immediately emits a rapid succession of sounds like *chwi* at the rate of about five per second and continues them an unlimited time. McNeil represents

the notes as *zip, zip, zip*; Davis expresses them as *ik, ik, ik*; and Allard hears them as *tsip, tsip, tsip*. The song of *retusus* (fig. 13) is quite different. It consists of a long shrill whirr which Rehn and Hebbard describe as a continuous *zzzzzzzzzzzz*. The sound is not loud but is of a very high key, and rises in pitch as the player gains speed in his wing movements, till to some human ears it becomes almost inaudible, though to others it is a plain and distinct screech.

A large conehead and one with a much stronger instrument is the robust conehead, *Neoconocephalus robustus* (fig. 14). He is one of the loudest singers of American Orthoptera, his song being an intense, continuous buzz, somewhat resembling that of a cicada. A caged specimen singing in a room makes a deafening noise. The principal buzzing sound is accompanied by a lower, droning hum, the origin of which is not clear but which is probably some secondary vibration of the wings. The player always sits head downward while performing, and the breathing motions of the abdomen are very deep and rapid. The robust conehead is an inhabitant of dry sandy places along the Atlantic coast from Massachusetts to Virginia and, according to Blatchley, of similar places near the shore of Lake Michigan in Indiana. The writer made its acquaintance in Connecticut on the sandy flats of the Quinnepiac Valley, north of New Haven, where its shrill song may be heard on summer nights from long distances.



FIG. 14.—The robust conehead, *Neoconocephalus robustus*, in position of singing, with fore wings separated and somewhat elevated, and head downward

THE MEADOW GRASSHOPPERS

These are trim, slim little grasshopperlike insects, active by day, that live in moist meadows where the vegetation is always fresh and juicy. They constitute the subfamily Conocephalinae of the katydid family, having conical heads like the last group, but being mostly

of smaller size. There are numerous species of the meadow grasshoppers, but most of them in the eastern part of the United States belong to two genera known as *Orchelimum* and *Conocephalus*. The most abundant and most widely distributed member of the first is the common meadow grasshopper, *Orchelimum vulgare*. A male is shown in Figure 15. He is a little over an inch in length, with head rather large for his size, and with big eyes of a bright orange color. The ground color of his body is greenish, but the top of the head and thoracic shield is occupied by a long triangular dark brown patch, while the stridulating area of the wings is marked by a brown spot at each corner. These little grasshoppers readily sing in confinement, both in the day and at night. Their music is very unpretentious and might easily be lost out of doors, consisting mostly of a soft, rustling buzz lasting two or three seconds. Often the buzz is preceded or followed by a series of clicks made by a slower movement of the wings. Frequently the player opens the wings for the start of the song with a single click, then proceeds with the buzz,

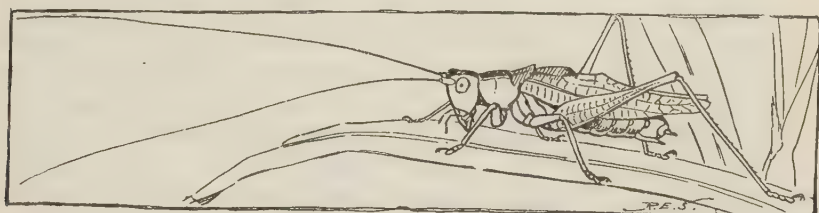


FIG. 15.—The common meadow grasshopper, *Orchelimum vulgare*, a member of the katydid family

and finally closes with a few slow movements that produce the concluding series of clicks. But very commonly he gives only the buzz without prelude or staccato ending.

Another common member of the genus is the agile meadow grasshopper, *Orchelimum agile*. Its music is said to be a long *zip, zip, zip, zee-e-e-e*, with the *zip* syllable repeated many times. These two elements, the *zip* and the *zee*, are characteristic of the songs of all the *Orchelimums*, some giving more stress to the first and others to the second, and sometimes either one or the other is omitted. A very pretty species of the genus is the handsome meadow grasshopper, *Orchelimum laticauda* (or *pulchellum*) shown in Figure 16. When at rest both males and females usually sit close to a stem or leaf with the middle of the body in contact with the support and the long hind legs stretched out behind. Davis says the song of this species is a *zip, zip, zip, z, z, z*, quite distinguishable from that of *O. vulgare*.

Still smaller meadow grasshoppers belong to the genus *Conocephalus*, more commonly called *Xiphidium*. One of the commonest

species, the slender meadow grasshopper, *C. fasciatus*, is shown in Figure 17. It is less than an inch in length, the body is green, the back of the thorax dark brown, the wings reddish-brown, and the back of the abdomen marked with a broad brown stripe. Allard says the song of this little meadow grasshopper may be expressed as *tip, tip, tip, tseeeeeeeeeeeeeee*, but that the entire song is so faint as almost to escape the hearing. Piers describes it as *plee-e-e-e-e-e, tzit, tzit, tzit, tzit*. Like the song of *Orchelimum vulgare* it apparently may either begin or end with staccato notes.



FIG. 16.—The handsome meadow grasshopper, *Orchelimum laticauda*. Upper, a male; lower, a female

large and very destructive bands. One such species is the Mormon cricket, *Anabrus simplex*, and another is the Coulee cricket, *Peranabrus scabricollis* (fig. 18), of the dry central region of the State of Washington. The females of these species are commonly wingless, but the males have short stubs of front wings that retain the stridulating organs and enable them to sing with a brisk chirp.

Still another large subfamily of the Tettigoniidæ is the Rhadophorinæ, including the insects known as camel crickets. But these are all wingless, and therefore silent.

THE SHIELD BEARERS

Another large group of the katydid family is the subfamily Decticinae, mostly cricketlike insects that live on the ground; but they have wings so short (fig. 18) that they are poor musicians and can claim but passing notice here. They are called "shield bearers" because the large back plate of the first body segment is more or less prolonged like a shield over the back. Most of the species live in the western parts of the United States where the individuals sometimes become so abundant as to form



FIG. 17.—The slender meadow grasshopper, *Conocephalus fasciatus*, one of the smallest members of the katydid family

THE CRICKET FAMILY

The chirp of the cricket is probably the most familiar note of all Orthopteran music. But the only cricket commonly known to the public is the black field cricket, the lively chirper of our yards and gardens. His European cousin, the house cricket, is famous as the "cricket on the hearth" on account of his fondness for fireside warmth which so stimulates him that he must express his animation in song. This house cricket has been known as *Gryllus* since the time of the ancient Greeks and Romans, and his name has been made the basis for the name of his family, the Gryllidæ, for there are numerous other crickets, some that live in trees, some in shrubbery, some on the ground, and others in the earth.

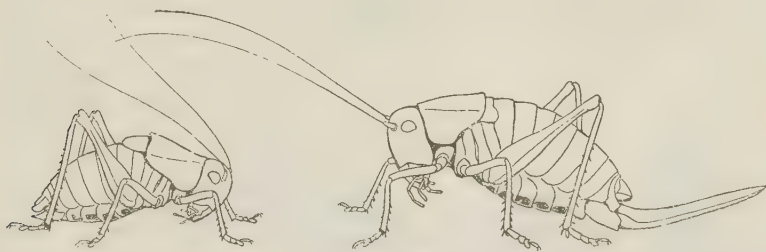


FIG. 18.—The Coulee cricket, *Peranabrus scabricollis*, male and female, an example of a cricket-like member of the katydid family

The crickets have long slender antennæ like those of the katydids, and also stridulating organs on the bases of the wings, and ears in their front legs. But they differ from the katydids in having only three joints in their feet (fig. 4, C). The cricket's foot in this respect resembles the foot of the grasshopper (A), but usually differs from that of the grasshopper in having the basal joint smooth or hairy all around or with only one pad on the under surface. In most crickets also the second joint is very small. Some crickets have large wings, others have small wings, some no wings at all. The females are provided with long ovipositors for placing their eggs in twigs of trees or in the ground (figs. 21, 22).

The musical or stridulating organs of the crickets are similar to those of the katydids, being formed from the veins of the bases of the front wings. But in the crickets the parts are equally developed on each wing, and it looks as if the crickets could play with either wing uppermost. Yet most of them consistently keep the *right* wing on top and use the file of this wing and the scraper of the left, just the reverse of the custom amongst the katydids. Yet there are exceptions to the rule amongst the crickets. It has been shown by Lutz that 2 per cent of a large number of individuals of the black field cricket, *Gryllus assimilis*, that he examined had the left wing

uppermost. He found also that they keep the wings through life in whatever position they have at maturity, but that if the wings are changed artificially at the last molt before they become dry and stiff the crickets kept them in this altered position and when mature sing as well as any of the others. Amongst the females a larger percentage have the left wing normally on top.

The front wings of male crickets are usually very broad and have the outer edges turned down in a wide flap that folds over the sides of the body when the wings are closed. The wings of the females are simpler and usually smaller. The differences between the front

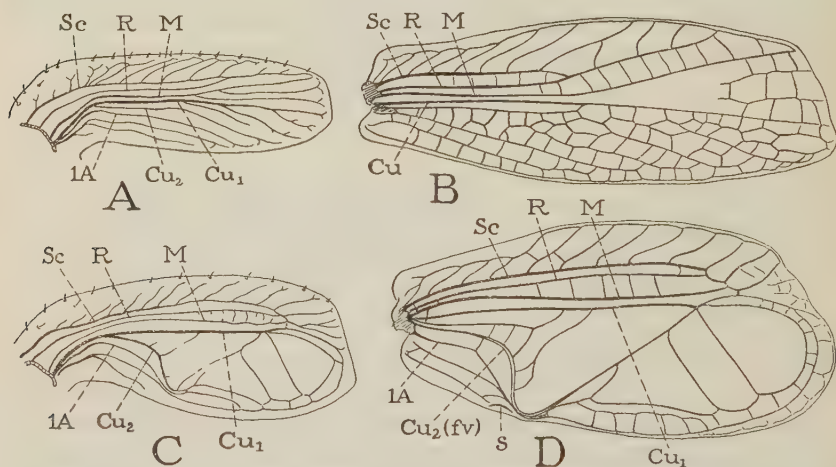


FIG. 19.—The wings of a tree cricket. A, right front wing of an immature female, showing normal arrangements of veins: *Sc*, subcosta; *R*, radius; *M*, media; *Cu*₁, first branch of cubitus; *Cu*₂, second branch of cubitus; *1A*, first anal. (From Comstock and Needham.) B, front wing of an adult female of the narrow-winged tree cricket. C, front wing of an immature male, showing widening of inner half to form vibrating area or tympanum, and modification of veins in this area. (From Comstock and Needham.) D, right front wing of adult male of the narrow-winged tree cricket, with veins identified according to Comstock and Needham. The second branch of cubitus (*Cu*₂) becomes the curved file vein (*fv*). *s*, the scraper

wings in the male and the female of one of the tree crickets (fig. 23) is shown at B and D of Figure 19. The inner half of the wing (or the rear half when the wing is extended) is very large in the male (D) and has only a few veins, which brace or stiffen the wide membranous vibratory area or *tympanum*. The inner basal part or *anal area* of the male wing is also larger than in the female and contains a prominent vein (*Cu*₂) which makes a sharp curve toward the edge of the wing. This vein has the stridulating file on its under surface. The veins in the wing of an adult female (B) are comparatively simple, and those of a young female cricket (A) are more so. But the complicated venation of the male wing has been developed from

the simple type of the female, which is that common to insects in general, as has been shown by Comstock and Needham. The wing of a young male (C) is not so different from that of a young female (A) but that the corresponding veins can be identified, as shown by the lettering. Going next to the wing of the adult male (D) it is an easy matter to determine what the veins are that have been so distorted to produce the stridulating apparatus. As Comstock says (Introduction to Entomology, p. 85): "It can be easily seen that the file is on that part of Cu_2 that is bent back toward the inner margin of the wing; the tympana are formed between the branches of cubitus (Cu_1 , Cu_2); and the scraper (s) is formed at the outer end of the anal area." When the tree crickets sing they elevate the wings above the back like two broad fans (figs. 23, 26) and move them sidewise so that the file of the right rubs over the scraper of the left.

THE MOLE CRICKETS

The mole crickets (fig. 20) are solemn creatures of the earth. They live like true moles in burrows underground, usually in wet fields or along streams. Their forefeet are broad and turned outward for digging like the front feet of moles. But the mole crickets differ from real moles in having wings, and sometimes they leave their burrows at night and fly about, being occasionally attracted to lights. Their front wings are short and lie flat on the back over the base of the abdomen, but the long hind wings are folded lengthwise over the back and project beyond the tip of the body.

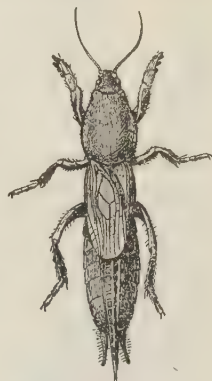


FIG. 20.—A mole cricket (*Neocurtilla hexadactyla*)

Notwithstanding the gloomy nature of their habitat the male mole crickets sing. Their music, however, is solemn and monotonous, being always a series of loud, deep-toned chirps, like *churp, churp, churp*, repeated very regularly about a hundred times a minute and continued indefinitely if the singer is not disturbed. Since the notes are most frequently heard coming from a marshy field or from the edge of a stream, they might be supposed to be those of a small frog. It is difficult to capture a mole cricket in the act of singing for he is most likely standing at an opening in his burrow, into which he retreats before he is discovered.

There are several species of mole crickets in the United States. The European one, *Gryllotalpa gryllotalpa*, has been introduced at a few places in the East. The common American species is *Gryllotalpa* or *Neocurtilla hexadactyla* (fig. 20), while a larger species, *N. major*, is known from the Middle West.

THE FIELD CRICKETS

This group of crickets includes *Gryllus* as its typical member, but entomologists give first place to a smaller brown cricket called *Nemobius*. There are numerous species of the genus, but a widely

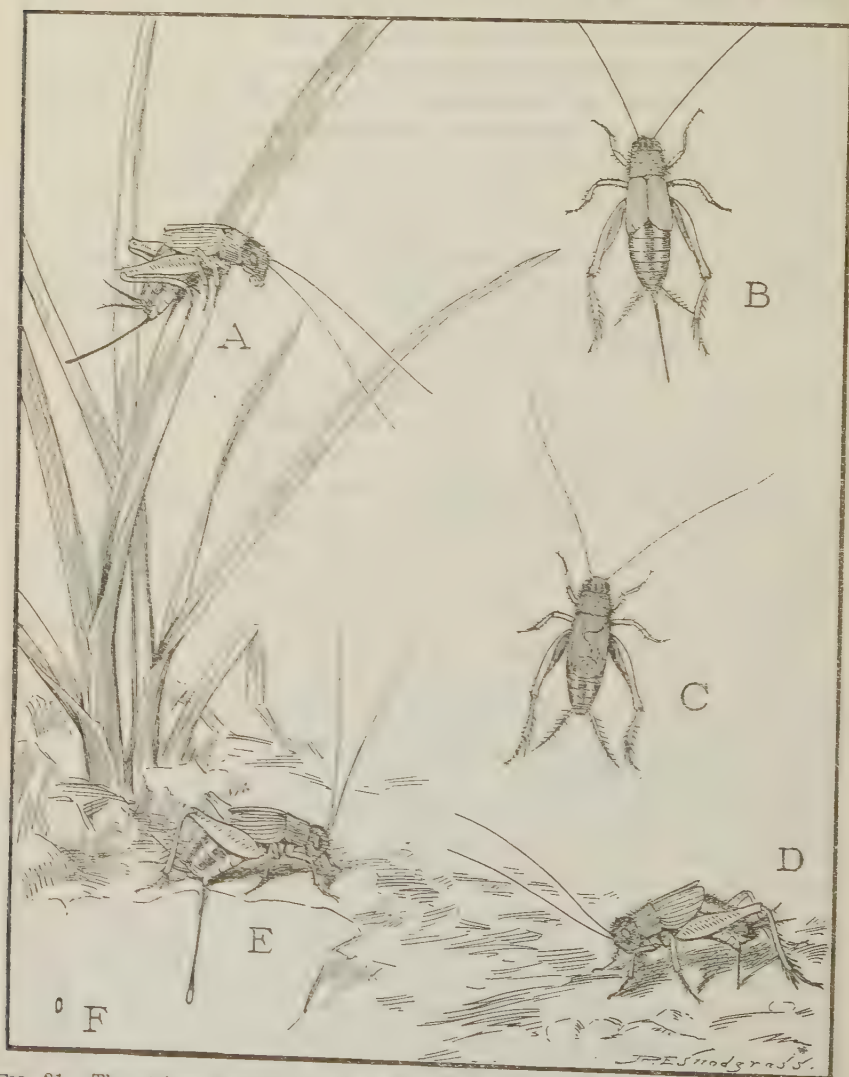


FIG. 21.—The striped ground cricket, *Nemobius fasciatus*. A, B, females. C, a male. D, a female in the act of thrusting her ovipositor into the ground. E, a female with ovipositor full length in the ground and extruding an egg from its tip. F, an egg in the ground

distributed one is *N. vittatus*, the striped ground cricket. This is a little cricket, about three-eighths of an inch in length, brownish in color, with three darker stripes on the abdomen, common in fields and dooryards (fig. 21). In the fall the females lay their eggs in

the ground with their slender ovipositors (D, E) and the eggs (F) hatch the following summer.

The song of the male *Nemobius* is a continuous twittering trill so faint that you must listen attentively to hear it. In singing the male raises his wings at an angle of about 45°. The stridulating vein is set with such fine ridges that they would seem incapable of producing even those whispering *Nemobius* notes. Most of the musical instruments of insects can be made to produce a swish, a creak, or a grating noise of some sort when handled with our clumsy fingers or with a pair of forceps, but only the skill of the living insect can bring from them the tones and the volume of sound they are capable of producing.

We now come to our friend *Gryllus*, the black cricket (Fig. 22) so common everywhere in fields and yards and occasionally entering houses. The true house cricket of Europe, *Gryllus domesticus*, has become naturalized in this country and occurs in small numbers through the Eastern States. But our common native species is *Gryllus assimilis*. Entomologists distinguish several varieties, though they are inclined to regard them all as belonging to the one species.

Mature individuals of *Gryllus* are particularly abundant in the fall; in southern New England they appear every year at this season by the millions, swarming everywhere, hopping across the country roads in such numbers that it is impossible to ride or walk without crushing them. Most of the females lay their eggs in September and October, depositing them singly in the ground (Fig. 22, D, E) in the same way that *Nemobius* does. These eggs hatch about the 1st of June the following year. But at this same time another group of individuals reaches maturity, a group that hatched in midsummer of the preceding year and passed the winter in an immature condition. The males of these begin singing at Washington during the last part of May, in Connecticut the 1st of June, and may be heard until the end of June. Then there is seldom any sound of *Gryllus* until the middle of August, when the males of the spring group begin to mature. From now on their notes become more and more common and by early fall they are to be heard almost continuously day and night until frost.

The notes of *Gryllus* are always vivacious, usually cheerful, sometimes angry in tone. They are merely chirps and may be known from all others by a broken or vibratory sound. There is little music in them but the player has enough conceit to make up for this lack. Two vigorous males that were kept in a cage together with several females gave each other little peace. Whenever one began to play his fiddle the other started up, to the plain disgust of the first one, and either was always greatly annoyed and provoked to anger if any of the

females happened to run into him while he was playing. If one male was fiddling alone and the other approached him, the first dashed at the intruder with jaws open, increasing the speed of his strokes at

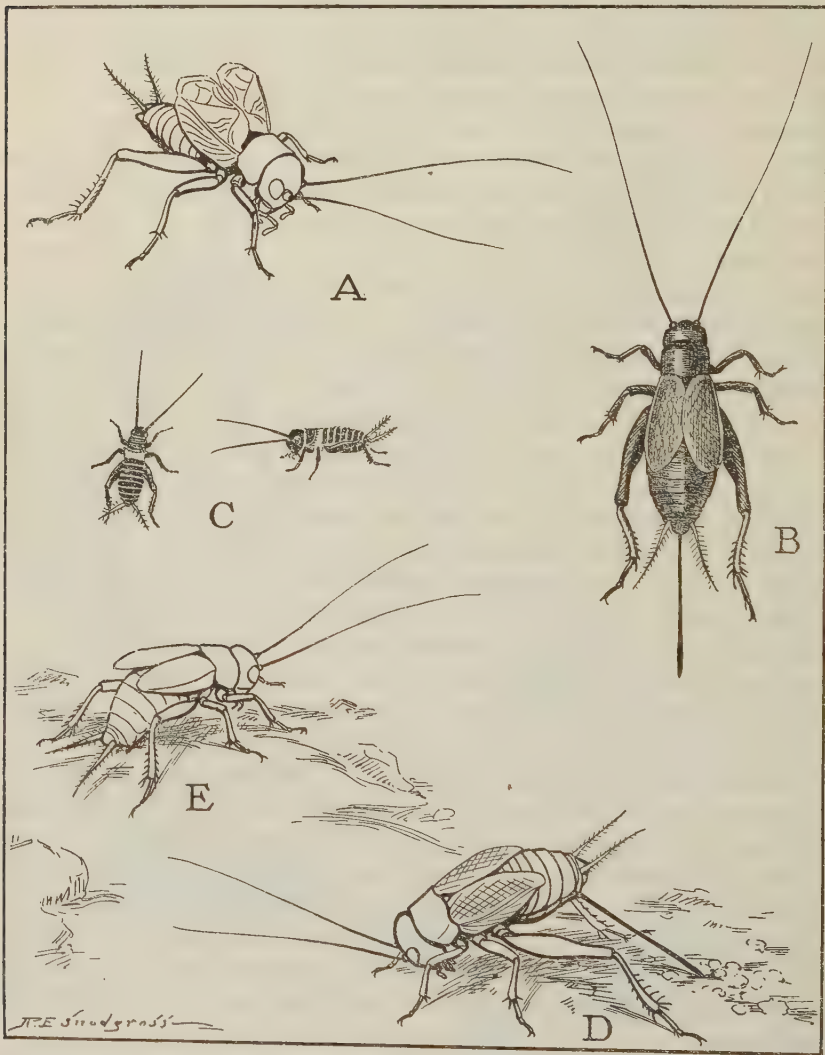


FIG. 22.—The common black cricket, *Gryllus assimilis*. A, male with wings raised in attitude of singing. B, female. C, young crickets recently hatched (enlarged three times). D, a female beginning to insert her ovipositor into the ground. E, female with ovipositor buried full length in ground

the same time till the notes became almost a shrill whistle. The other male usually retaliated by playing too, in an apparent attempt to outfiddle the first. The chirps from both sides now came quicker and quicker, their pitch mounting higher and higher till each player reached his limit. Then both would stop and begin over again.

Neither male ever inflicted any actual damage on his rival, and in spite of their savage threats, neither was ever seen really to grasp any part of the other with his jaws. Either would dash madly at a female that happened to disturb him while fiddling, but neither was ever seen to threaten a female with open jaws.

The weather has much influence on the spirits of the males; their chirps are always loudest and their rivalry keenest when it is bright and warm. Setting their cage in the sun on cold days always started the two males at once to singing. Out of doors, though the crickets sing in all weather and at all hours, variations of their notes in tone and strength according to the temperature are very noticeable. This is not due to any effect of humidity on their instruments, for the two belligerent males kept in the house never had the temper on cold and gloomy days that characterized their actions and their song on days that were warm and bright. This, in connection with the fact that their music is usually aimed at each other in a spirit clearly suggestive of vindictiveness and anger, is all good evidence that *Gryllus* sings to *express himself* and not to "*charm the females*." In fact, it is often hard to feel certain whether he is singing or swearing. If we could understand the words we might be shocked at the awful language he is hurling at his rival. However, swearing is only a form of emotional expression, and singing is another. *Gryllus*, like an opera singer, simply expresses *all* his emotions in music, and, whether we can understand the words or not, we understand the sentiment.

At last one of the two caged rivals died; whether from natural causes or by foul means was never ascertained. He was alive early on the day of his demise but apparently weak, though still intact. In the middle of the afternoon, however, he lay on his back, his hind legs stretched out straight and stiff; only a few movements of the front legs showed that life was not yet quite extinct. One antenna was lacking and the upper lip and adjoining parts of the face were gone, evidently chewed off. But this is not necessarily evidence that death had followed violence, for in cricketdom violence more commonly follows death; that is, cannibalism is substituted for interment. A few days before, a dead female in the cage had been devoured quickly, all but the skull. After the death of the male the remaining one no longer fiddled so often, nor with the same sharp challenging tone as before. Yet this could not be attributed to sadness; he had despised his rival and had clearly desired to be rid of him; his change was due rather to the lack of any special stimulus for expression.

THE TREE CRICKETS

The unceasing ringing that always rises on summer evenings as soon as the shadows begin to darken, that shrill melody of sound that seems to come from nothing but from everywhere out of doors, is mostly the chorus of the tree crickets, the blend of notes from innumerable harpists playing unseen in the darkness. This sound must be the most familiar of all insect sounds, but the musicians themselves are but little known to the general public. And when one



FIG. 23.—The snowy tree cricket, *Oecanthus niveus*. Two upper figures males, the one on right with wings raised vertically in attitude of singing; below a female, with narrow wings folded close to body

of them happens to come to the window or into the house and plays in solo the sound is so surprisingly loud that the player is not suspected of being one of that band whose mingled notes are heard outside softened by distance and muffled by screens of foliage.

Out of doors the music of an individual cricket is so elusive that even when you think you have located the exact bush or vine from which it comes, the notes seem to shift and dodge—surely you think the player must be under that leaf, but when you approach your ear to it the sound as certainly comes from another over yonder, but here you are equally convinced again that it comes from still another place farther off. Finally, though, it strikes the ear with such in-

tensity that there can be no mistaking the source of its origin, and right there in plain sight on a leaf sits a little, delicate, slim-legged, pale green insect with hazy transparent sails outspread above its back. But can such an insignificant creature be making such a deafening sound! It has required very cautious tactics to have approached thus close without stopping the music, and it needs but a touch on stem or leaf to make it cease. But now those gauzy sails that before were a blurred vignette have acquired a definite outline, and a little more disturbance may cause them to be lowered and spread flat on the creature's back. The music will not begin anew until you have passed a period of silent waiting. Then suddenly those lacy films go up, once more their outlines blurr, and that intense scream again pierces your ear. In short, you are witnessing a private performance of the broad-winged tree cricket, *Oecanthus latipennis*.

But if you pay attention to the notes of other singers you will observe that there is a variety of airs in the medley going on. Many others are long trills like the one just identified, lasting indefinitely, but others are softer, purring notes about two seconds in length, while still others are short beats repeated regularly a hundred or more times every minute. The last are the notes of the snowy tree cricket, *Oecanthus niveus*, so-called on account of his paleness. He is really green in color, but a green of such a very pale shade that he looks almost white in the dark. The male (fig. 23) is a little longer than half an inch, his wings are wide and flat, overlapping when folded on the back, with the edges turned down against the sides of the body. The female is heavier bodied than the male, but her wings are narrow and when folded are furled along the back. She has a long ovipositor for inserting her eggs into the bark of trees.

The males of the snowy cricket reach maturity and begin to sing about the middle of July. The singer raises his wings vertically above the back and vibrates them sideways so rapidly that they are momentarily blurred with each note. The sound is that *treat, treat, treat, treat* already described, repeated regularly, rhythmically, and monotonously all through the night. At the first of the season there may be about 125 beats every minute, but later, on hot nights, the strokes become more rapid and mount to 160 a minute. In the fall again the rate decreases on cool evenings to perhaps a 100. And finally, at the end of the season, when the players are benumbed with cold, the notes become hoarse bleats repeated slowly and irregularly as if produced with pain and difficulty.

The several species of tree crickets belonging to the genus *Oecanthus* are similar in appearance, though the males differ somewhat in the width of the wings and some species are more or less diffused

with a brownish color. But on their antennæ most species bear distinctive marks (fig. 24) by which they may be easily identified. The snowy cricket, for example, has a single oval spot of black on the under side of each of the two basal antennal joints (fig. 24, C). Another, the narrow-winged tree cricket, has a spot on the second joint and a black J on the first (A, B). A third, the four-spotted cricket (D), has a dash and dot side by side on each joint. A fourth, the black-horned or striped tree cricket (E), has two spots on each joint more or less run together, or sometimes has the whole base of the antenna blackish, while the color may also spread over the fore parts of the body and, on some individuals, form stripes along the back. A fifth species, the broad-winged (F), has no marks on the antennæ, which are uniformly brownish.

The narrow-winged tree cricket is almost everywhere associated with the snowy, but its notes are very easily distinguished. They con-

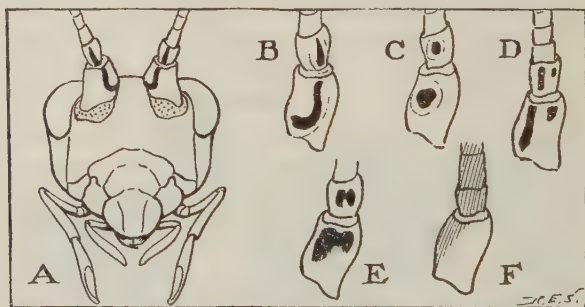


FIG. 24.—Marks on two basal segments of antennæ distinguishing different species of tree crickets

A, B, *Oecanthus angustipennis*. C, *nireus*. D, *quadripunctatus*. E, *nigricornis*. F, *latipennis*.

sist of slower, purring sounds usually prolonged about two seconds and separated by intervals of the same length, but as fall approaches they become slower and longer. Always they are sad in tone and sound far off.

The three other common tree crickets, the black-horned or striped cricket, *Oecanthus nigricornis*, the four spotted, *O. nigricornis quadripunctatus*, and the broad-winged, *O. latipennis*, are all trillers; that is, their music consists of a long, shrill whirr kept up indefinitely. Of these the broad-winged cricket makes the loudest sound and the one predominant near Washington. The black-horned is the common triller farther north, and is particularly a daylight singer. In Connecticut his shrill note rings everywhere along the roadsides on warm bright afternoons of September and October as the player sits on leaf or twig fully exposed to the sun. At this season also both the snowy and the narrow-winged sing by day, but usually later in the afternoon and generally from more concealed places.

We should naturally like to know why these little creatures are such persistent singers and of what use their music is to them. Do the males really sing to charm and attract the females as is usually presumed? We do not know; but sometimes as a male sings a female approaches him from behind, noses about on his back and soon finds there a deep basin-like cavity situated just behind the bases of the elevated wings. This basin contains a clear liquid which the female proceeds to lap up very eagerly as the male remains quiet with wings upraised though he has ceased to play (fig. 25). We must suspect, then, that in this case the female has been attracted to the male rather by his confectionery offering than



FIG. 25.—A female tree cricket feeding on the liquid exuded from the back of the male while the latter holds his wings elevated in attitude of singing. (*Oecanthus angustipennis*, enlarged $3\frac{1}{2}$ times)

by his music. The purpose of the latter, therefore, would appear to be to advertise to the female the whereabouts of the male, who she knows has sweets to offer, or if the liquid is sour or bitter it is all the same, the female likes it and comes after it. If, now, this luring of the female sometimes ends in marriage we may see here the real reason for the male's possessing his music-making organs and his instinct to play them so continuously.

A male cricket with his front wings raised and seen from above and behind as he might look to a female is shown in Figure 26. The basin (*B*) on his back is a deep cavity on the dorsal plate of the third thoracic segment. Two deeper pits in the bottom are covered with fringes of long hairs, which Parrott and Fulton say are glandular. But also a pair of large branching glands (fig. 27, *Gl*) within the body open just inside the rear lip of the basin,

and these glands must furnish the bulk of the liquid that the female obtains.

There is another kind of tree cricket belonging to another genus, *Neoxabia*, called the two-spotted tree cricket, *N. bipunctata*, on account of two pairs of dark spots on the wings of the female.* This cricket is larger than any of the species of *Oecanthus* and is of a pinkish-brown color. It is widely distributed over the eastern half of the United States, but is comparatively rare and seldom met with. Allard says its notes are low, deep, mellow trills continued for a few seconds and separated by short intervals, as are the notes of the narrow-winged *Oecanthus*, but that their tone more resembles that of the notes of the broad-winged.

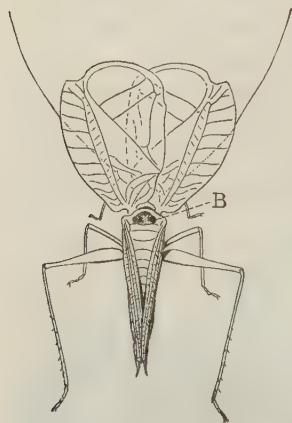


FIG. 26.—A male of the broad-winged tree cricket with wings elevated in position of singing, seen from above and behind, showing the basin (B) on his back into which the liquid is exuded that attracts the female

THE BUSH CRICKETS

The bush crickets differ from the other crickets in having the middle joint in the foot larger and shaped more like the third joint in the foot of a katydid (fig. 4, B). Amongst the bush crickets there

is one notable singer very common in the neighborhood of Washington. This is the jumping bush cricket, *Orocharis saltator*, who comes on the stage late in the season, about the middle of August or shortly after. His notes are loud, clear, piping chirps with a rising inflection toward the end, suggestive of the notes of a small tree toad, and they at once strike the listener as something new and different in the insect program. The players, however, are at first very hard to locate, for they do not perform continuously—one note seems to come from here, a second from over there, and a third from a different angle, so that it is almost impossible to place any one of them. But after a week or so the crickets become more numerous and each player more persistent till soon the notes are the predominant sounds in the nightly concerts, standing out loud and clear against the whole tree cricket chorus. As Riley says, this chirp "is so distinctive that when once studied it is never

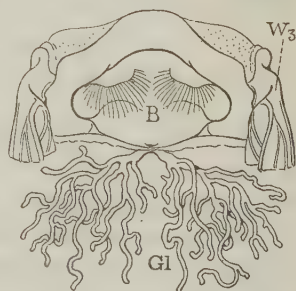


FIG. 27.—The back of the third thoracic segment of the broad-winged tree cricket, with its basin (B) that receives the secretion from the glands (Gl) inside the body

lost amid the louder racket of the katydids and other night choristers."

After the 1st of September it is not hard to locate one of the performers, and when discovered with a flash light, he is found to be a medium-sized, brown, short-legged cricket, built somewhat on the style of *Gryllus* but smaller (fig. 28). The male, however, while singing raises his wings straight up, after the manner of the tree crickets, and he too carries a basin of liquid on his back much sought after by the female. In fact the liquid is so attractive to her that, at least in a cage, she is sometimes so persistent in her efforts to obtain it that the male is clearly annoyed and tries to avoid her. One male was observed to say very distinctly by his actions as he repeatedly tried to escape the nibbling of a female, presumably his wife since she was taken with him when captured, "I do wish you would quit pestering me and let me sing!" Here is another piece of evidence suggesting that the male cricket sings to express his own emotions, whatever they may be, and not primarily to attract the female. But if, as in the case of the tree crickets, his music tells the female where she may find her favorite confection and this in turn leads to matrimony, when the male is in the proper mood, it suggests a practical use and a reason for the stridulating apparatus of the male.



FIG. 28.—The jumping bush cricket, *Orocharis saltator*. Male above, female below

THE CICADA FAMILY

The cicada (fig. 29) needs but little introduction when it is explained that he is the insect popularly though incorrectly known as the "locust." The loud song of those species that come every year is always a feature of the season's daytime program from midsummer till early fall, while the chorus of the 17-year species is a special event of early summer wherever and whenever a brood appears.

The ancient Greeks knew the cicada, but called him Tettix. They appreciated his music to such an extent that they kept him captive in cages to hear him sing. Æsop, however, who always

found the weak spot in everybody's character, wrote a fable about the Tettix and the ant in which the Tettix, or cicada, after having sung all summer, asked a bit of food from the ant when the chill winds of coming winter struck him unprovided. But the practical ant replied: "Well, now you can dance." This is a very unjust piece of satire, because the moral is drawn in favor of the ant. Human musicians have learned their lesson and sign their contracts with the box-office management in advance. But the whole story about the cicada and the ant is a very improbable tale, because the cicada can eat only liquid food and the common ant keeps only solid provender in his cellar. All the cicadas have a long beak



FIG. 29.—One of the cicadas that are heard every year, *Tibicen pruinosa* (a little larger than natural size)

through which they extract sap from the twigs of trees, if they take any food at all (see pp. 393 to 396 of Smithsonian Report for 1919), and the cicada of the fable would have starved on anything the ant might have offered.

There are a number of species of cicadas that come every year. They are known as locusts, harvest flies, and dog-day cicadas, and are the insects that sit in the trees on warm afternoons and make those long, shrill sounds so suggestive of hot weather. Some give a rising and falling tone to their song, like *zwing, zwing, zwing, zwing*, others a rattling sound, and still others make just a continuous whistling buzz. Then there is the 17-year species that appears in large swarms somewhere every few years. Each individual lives in

the earth for most of 17 years in immature stages, but there are many broods and each brood has its emergence year independent of the others. In the South there is a 13-year race of this same species. Any large brood of the periodical cicada creates a great disturbance when it issues and the matured adults begin their daily choruses in the trees. The first notes are soft purring sounds, generally heard from individuals sitting low in the bushes, probably those that have but recently emerged from the ground. The next is a longer note, characterized by a rougher or *burr* sound lasting about five seconds, always with a falling inflection at the end. This song is popularly known as the "Pharaoh" note. Finally, when the swarm is collected in the trees, there is the grand concert of long *burr-r-r-r*-like notes, repeated all day and day after day till the middle of June, by which time the females have deposited the eggs for the next generation, and the concerts end with the death of the performers.

The cicadas belong to a different order of insects from that of the grasshoppers, katydids, and crickets, being members of the Hemiptera, all of which have sucking instead of biting mouth parts. The cicadas, moreover, produce their music by a quite different method from that used by any



FIG. 30.—A male of the 17-year cicada (*Tiboloina septendecim*), with wings elevated to show the sound-producing drums or tympana (*Tm*) on the sides of the first abdominal segment

of the Orthoptera. Just back of the base of each hind wing, in the position of the ear of the grasshopper, there is an oval membrane like the head of a drum set into a solid rim of the body wall. In the periodical cicada the drums are exposed and are easily seen when the wings are lifted (fig. 30, *Tm*). In most of the other species they are covered by a flap of the body wall. The cicada, however, does not beat his drums; the drum heads are set into vibration by a pair of great muscles attached to them inside the body (fig. 31, A, B, *TmMcl*). Each drum or tympanum (*Tm*) is ribbed, the number of ribs varying with different species.

A membrane or thin sheet of any material which produces a sound by vibrating must have air of equal pressure on both sides of it and air free to respond to any changes of pressure. The drum head of the cicada thus could produce no sound if its inner face were in contact with the viscera or blood of the body cavity, and between the two tympana there is actually a great air cavity which extends

far back into the abdomen (fig. 31, A, *Air Sc*). Its walls are very thin and are closely applied to the inner faces of the tympana. The whole abdomen of the cicada is, therefore, virtually a drum. Besides the drum heads themselves there are two other pairs of large membranes in the body wall below them, likewise covered internally by the walls of the air sac. One pair of these membranes is particularly thin and tense and must act as secondary resounding boards to give added resonance to the sound produced by the drums. These lower membranes are concealed above valvelike flaps of the body wall projecting backward below them, but when the cicada begins to play his drums he elevates the abdomen a little and thus opens the space

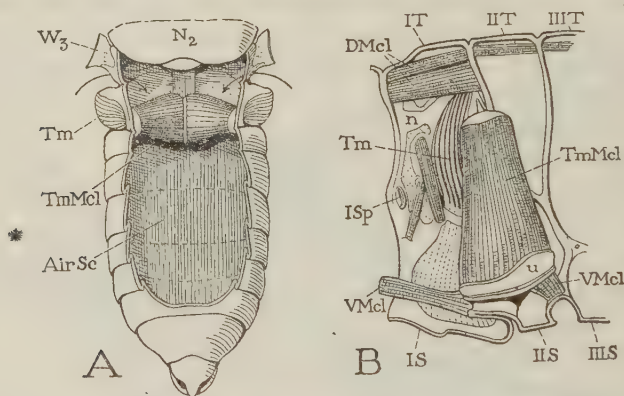


FIG. 31.—The abdomen and sound-making organs of the 17-year cicada. A, the abdomen cut open from above to show the large air sac (*AirSc*) it contains, and the great tympanal muscles (*TmMcl*) that vibrate the drums or tympana (*Tm*). *N*₂, the back of the third thoracic segment carrying the hind wings (*W*₃) cut off near their bases. The arrows indicate the position of the air holes or spiracles on the sides that open into the air sac. B, inner view of right side of first two segments of abdomen, showing the right tympanal muscle (*TmMcl*) attached to the tympanum (*Tm*) and the spiracle (*ISp*) of the first segment; *IT*—*IIIT*, *IS*—*IIIS*, dorsal and ventral plates of first three abdominal segments; *DMcl*, *VMcl*, dorsal and ventral longitudinal muscles; *n*, hinge between abdomen and thorax; *u*, supporting plate of tympanal muscles

between the membranes and their coverings. At the end of the song the abdomen drops down again.

It has generally been supposed that the air chamber of the cicada's body is a part of the tracheal or respiratory system, corresponding with the smaller air sacs of other insects; but a recent investigator, L. M. Hickernell, claims that it is a part of the alimentary canal. The present writer described and figured it in a former paper (p. 403, Smithsonian Report for 1919) as a tracheal air sac receiving its air through the first spiracles or breathing pores of the abdomen. Since then he has examined other species and finds these spiracles always opening directly into the sac, as indicated by the arrows on Figure 31, A. In freshly emerged individuals of one species the sac is clearly double, being divided

lengthwise by a medium septum. It is present in the females, which shows that it is not necessarily an accessory of the sound-producing apparatus, though it has become a necessary part of this organ in the male. If it is a part of the alimentary canal it is difficult to explain how it is always full of gas, and if this gas does not communicate with the exterior air, as does the air in an ordinary musical drum, it is difficult to see why it should not impede the vibration of the tympana. The anatomy of these parts needs yet further investigation.

A well-known writer of popular fiction says this of the cicada: "These wing shields" (meaning the front wings) "are divided into several sections by the veins that hold the transparent parts securely, and the outer edge has a stout rim. Using these rims for the strings, the crisp space for sounding boards, and the femur of the hind legs for bows, the locust amazed us by not singing at all, for he fiddled away gayly as he led the insect orchestra." This is bad enough, but the paragraph ends thus, "and they even played in flight. I could not see how they flew, and fiddled on the wing shields at the same time, but repeatedly I saw them do it." An accompanying photograph leaves no doubt of the identity of the insect described—it is the 17-year locust or cicada. No particular harm is done when a scientist makes a mistake and writes something that is not true, because his works are read by few except other scientists, and they soon take him to account for his error; but it is deplorable when a popular writer becomes careless of the facts, because his or her statements are read by the multitude uneducated in matters of natural history and are widely accepted as the truth.

THE SUPPOSED HEARING ORGANS OF INSECTS

After seeing how well provided some insects are with sound-producing organs, our curiosity is aroused to know what sound-receiving apparatus they possess. But here at once we are confronted by that gulf which separates the external from the internal, the physical from the psychic. If by some magic one of us could be transformed for a day into an insect and thus be permitted to think with its brain, feel with its nerves, and perceive with its sense organs, we should know much more about insect psychology than we probably ever shall know by our methods of dissection and experimentation. Insect sense organs are so different from our own that even an accurate knowledge of their structure gives us no certain index of their use, and conclusive experiments on their functions are so difficult to devise and so difficult to conduct that there is yet little unanimity of opinion on any of the senses of insects except that of sight.

As to organs of hearing, everyone knows that insects do not have ears such as ours on the sides of their heads, yet it is surprising to most people to learn that some of them may have auditory organs on the sides of the body or in the legs. The grasshopper, for example,



FIG. 32.—The Carolina locust, a grasshopper (*Dissosteira carolina*), with front wing elevated to show the large "ear" (e) on side of first abdominal segment. ($1\frac{1}{4}$ times natural size)

has a large cavity on each side of its first abdominal segment which has a tense eardrumlike membrane or tympanum stretched over its inner surface (fig. 32, e). Air sacs lie against the inside face of the

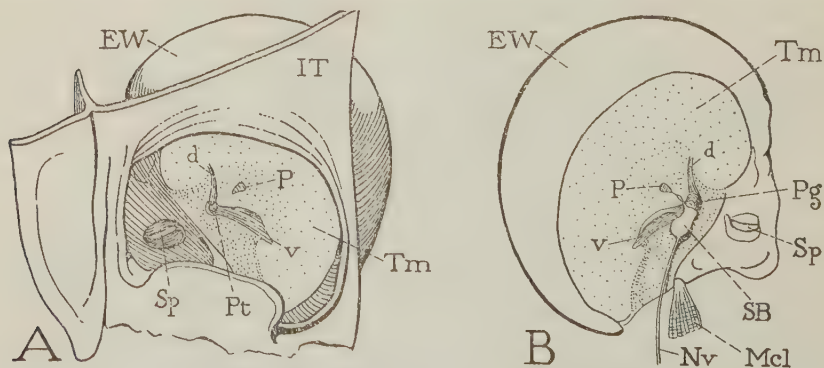


FIG. 33.—Details of the "ear" of the Carolina locust (greatly enlarged). A, external view of the ear in surrounding part of first abdominal segment (IT). d, upper supporting arm of internal peg (B, Pg) of tympanum; EW, wall of external ear cavity; P, pear-shaped thickening of tympanum; Pt, external pit of tympanum forming the internal peg (B, Pg); Sp, first abdominal spiracle; Tm, tympanum; v, lower supporting arm of the tympanal peg. B, inner view of the wall of the ear cavity (EW), the tympanum (Tm) and other parts shown in A. The external pit (A, Pt) forms a large internal peg (Pg) to which is attached the sense body or Müller's organ (SB) which receives the auditory nerve (Nv). Mcl, the tensor muscle of the tympanum

membrane, which would seem to furnish the proper statical condition to allow it to vibrate freely with sound waves of the air. Attached to the inner surface of the tympanum, moreover, there is a complicated sensory apparatus (fig. 33, B). This consists of a cellular body (SB) known as Müller's organ, which is continuous

at its outer end with the hypodermis or cellular layer of the body wall and at its inner end with a nerve (*Nv*) from one of the ventral ganglia. The organ consists of a main body and a slender branch. The former is attached by a wide base to a hollow peglike ingrowth of the tympanum (*Pg*), formed by a pit on the external surface

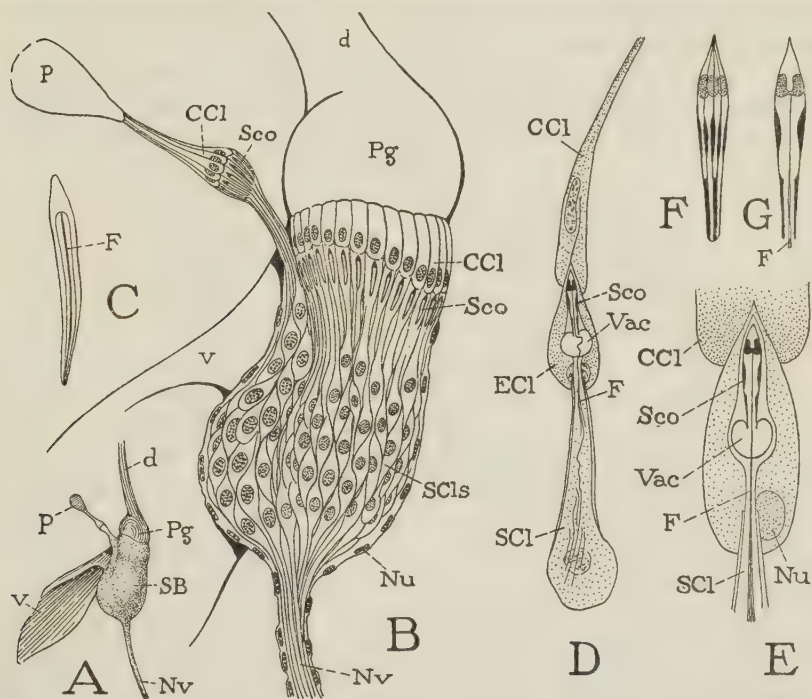


FIG. 34.—Details of sensory structures of the grasshopper's ear. A, the tympanal sense body or Müller's organ (*SB*) of *Dissosteira carolina*, attached to the peg (*Pg*) and the pear-shaped thickening (*P*) of the tympanum. *d*, *v*, thickenings of the tympanum forming dorsal and ventral arms supporting the peg (*Pg*). B, the same more enlarged and showing internal structure of the sense body, which has two divisions, the larger attached to the peg (*Pg*), the other attached to the pear-shaped support (*P*). *CCl*, cap cells; *d*, dorsal arm of peg; *Nu*, nucleus of enclosing membrane; *Nv*, nerve; *P*, pear-shaped support of branch of sense body; *Pg*, peg supporting main part of sense body; *Scl*s, sense cells; *Sco*, scolopala; *v*, ventral arm of peg. C, a scolopala and its axial fiber (*F*), greatly enlarged. D, a single series of cells from the sense body of *Acridium aegypticum* (from Schwabe), consisting of a cap cell (*CCl*), an enveloping cell (*ECI*), and a sense cell (*Scl*). The enveloping cell contains a scolopala (*Sco*) and a vacuole (*Vac*), both traversed by a fiber (*F*) from the sense cell. E, details of an enclosing cell and scolopala (from Schwabe). F, surface view of a scolopala, greatly magnified; G, optical section of the same (from Schwabe).

(*A*, *Pt*). The peg is supported by two arms or thickenings of the tympanum (*d*, *v*) that make a wide angle with each other. The branch of the sense body is attached to a pear-shaped thickening (*P*) of the tympanum.

The sense body itself consists of a mass of cells arranged in two groups (fig. 34, B), one forming the main part of the body connected with the peg (*Pg*), and the other prolonged into the branch sup-

ported by the pear-shaped nodule (*P*) of the tympanum. The cells directly attached to the peg form a thick outermost layer of large cells called the cap cells (*CCl*). Internal to them is a region of slenderer cells containing minute, brownish, peg-shaped rods known as the scolopalæ (*Sco*). The basal part of the organ consists of a mass of oval cells called the sense cells (*SCl*s) because their inner ends are in direct continuity with fibers of the nerve (*Nv*). The branch of the sense body swells at its middle to a spindle-shaped thickening containing the same elements as the other part, viz. long-

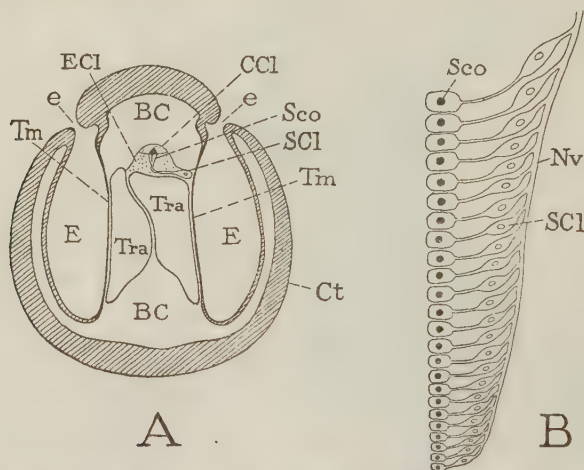


FIG. 35.—The "auditory organ" of the front leg of *Decticus*, a member of the katydid family (simplified from Schwabe). A, cross-section of the leg through the auditory organ, showing the ear slits (*e*) leading into the large ear cavities (*E, E*) with the tympana (*Tm, Tm*) on their inner faces. Between the tympana are two tracheæ (*Tra, Tra*) dividing the leg cavity into an upper and a lower channel (*BC, BC*). The sensory apparatus forms a crest on the outer surface of the inner trachea, each element consisting of a cap cell (*CCl*), an enveloping cell (*ECI*) containing a scolopala (*Sco*), and a sense cell (*SCl*). *Ct*, the thick cuticula forming the hard wall of the leg. B, surface view of the "crest" of the trachea, showing the sensilla graded in size from above downward. The sense cells (*SCl*) are attached to the nerve (*Nv*) along the inner side of the leg.

necked cap cells (*CCl*) attached to the support (*P*), and proximal cells containing scolopalæ (*Sco*) and prolonged basally to the sense cells.

It is evident that the essential parts of this organ must be the scolopalæ since they are the only distinctive structures in it. These rods may be separated from the enveloping cells by gently dissecting and crushing the sense body, and one so isolated is shown at C of Figure 34. The detail structure of a scolopala and its inclosing cells, as described by Schwabe, is shown at D, E, F, and G. The scolopalæ (*D, Sco*) and a large vacuole (*Vac*) at its base are contained in the enveloping cell (*ECI*). The vacuole, according to

Schwabe, contains a transparent liquid, and both vacuole and scolopala are traversed by a fine fiber (*F*) from the sense cell, which ends in a dark body occupying the tip of the scolopala (*G*).

Since no two investigators have described the scolopalæ or their enveloping cells exactly alike, too much reliance should not be placed on the details as given by any particular writer; but scolopalæ in similar combinations of cells are found widely distributed in special organs of many insects. The so-called "ear" in the front leg of a cricket or katydid has a structure essentially the same as that of the abdominal organ of the grasshopper. There is an oval tympanum on each side of the tibia near its upper end, and between the two there are tracheal air tubes apparently giving a balanced air pressure on both surfaces. In the crickets the tympana are exposed on the surface of the leg; in the katydids they are concealed in pockets (fig. 35, *E, E*) opening by narrow slits on the surface (figs. 6, *D*, and 35, *A, e*). On the outer face of the inner trachea of the two between the tympana there is a long crest, a cellular mass consisting of external cap cells (fig. 35, *A, CCl*), and of internal enveloping cells (*ECl*) containing short scolopalæ (*Sco*) and connected with a series of sense cells (*SCl*) that receive branches from a nerve (*B, Nv*) lying along the inner edge of the trachea. The scolopalæ and their containing cells in this organ decrease in size from above downward, as shown at *B* of Figure 35, and this has suggested that they are sound-receiving organs graded to respond to different notes. There are other sensory cell groups associated with this structure in the crickets and katydids which make the tibial organs of these insects somewhat more complicated than shown in the figure.

The connection of the scolopala-containing cells with eardrumlike membranes in the Orthoptera is the principal evidence in favor of the idea that they are auditory organs. But similar structures occur in other insects that have no vibratory surfaces. In the legs of the honeybee, as described by McIndoo, and in other Hymenoptera there are groups of cells containing scolopalæ. These are connected at one end with the hypodermis and at the other with a nerve and have the same essential structure as the tympanal sense body of the grasshopper, except for the lack of the tympanum. Likewise some insect larvæ have similar cell structures in the sides of the body segments, but these are suspended by cords and have received the name of chordotonal organs.

Experimental evidence of the hearing powers of insects is at present very meager, but it would be surprising if insects do not hear the sounds they themselves produce. Many insects have sense organs in the second joint of the antenna, which are most highly developed in

the gnats and mosquitoes, and in these forms have been described as containing rods similar to the scolopalæ. Some writers believe that these are organs of hearing.

Our ignorance or lack of exact knowledge of the senses of insects in general suggests that the next important line of investigation in entomology should be in the direction of a study of their psychic activities, call them tropisms, or what you will. A more intimate understanding of the senses and perceptive powers of insects is important scientifically and practically as leading to a more intelligent development of methods for combating those species that are inimical to us.

THE GARDENS OF ANCIENT MEXICO¹

By ZELIA NUTTALL

[With 4 plates]

As a preliminary to a description of the gardens of ancient Mexico it should be mentioned here that in the language of the Nahuas are found names descriptive of different kinds of gardens, a significant fact from which a prolonged familiarity with horticulture may be inferred. The name for a garden in general was *xochitla*, lit.=flower place; a variant being *xoxochitla*=place of many flowers. A walled garden was *xochitepanyo*. The pleasure gardens of the ruling class were designated as *xochitepancalli*, lit.=the palace of flowers. The humble garden of the Indian was and is a *xochichinancalli*, lit.=flower place inclosed by a fence made of cane or reeds.

These words reveal that the native conception of a garden was a flowery "*hortus inclusus*," which brings the ancient Mexican garden lovers very close to us. For a knowledge of the lordly pleasantries which delighted their owners at the time of the Conquest we have to rely upon the descriptions of Spanish eyewitnesses, which, exaggerated as they may seem, are fully corroborated by the native historians, and in the case of the Texcocan gardens by archeological remains. The most detailed description of a native garden is that written by Cortés in his second letter to the Emperor Charles V, in 1520, in the portion referring to his arrival at Iztapalapa, a town 7 miles distant from Mexico on the shore of the salt lagoon. He writes: "Its lord or chief has some new houses which, though still unfinished, are as good as the best in Spain; I mean as large and well constructed, not only in the stonework but also in the woodwork, and all arrangements for every kind of household service, all except the relief work and other rich details which are used in Spanish houses but are not found here. There are both upper and lower rooms and very refreshing gardens with many trees and sweet-scented flowers, bathing places of fresh water, well constructed and having steps leading down to the bottom. He also has a large orchard near the house, overlooked by a high terrace with many beautiful corridors and rooms. Within the orchard is a great square pool of fresh water, very well constructed, with sides of handsome masonry, around which runs a walk with a well-laid pavement of tiles, so wide that four persons can walk abreast on it, and 400 paces square, mak-

¹ Reprinted by permission from the Journal of the International Garden Club, December, 1922.

ing in all 1,600 paces. On the other side of this promenade toward the wall of the garden are hedges of lattice work made of cane, behind which are all sorts of plantations of trees and aromatic herbs. The pool contains many fish and different kinds of water-fowl * * *."

The observant Bernal Diaz, who accompanied Cortés, wrote enthusiastically about Iztapalapa as follows:

The garden and orchard are most admirable. I saw and walked about in them and could not satiate myself sufficiently looking at the many kinds of trees and enjoying the perfume of each. And there were walks bordered with the roses of this country and flowers and many fruit trees and flowering shrubs; also a pool of fresh water. There was another thing worth seeing, namely, that large canoes could enter into the flower garden from the lagoon through an entrance they had made of many kinds of stone covered with polished stucco and painted, which gave one much to think about. * * * Again I say that I do not believe that in the whole world there are other countries known to compare with this one.

It may well be that the gardens of Iztapalapa were in his mind when, 30 years after the Conquest, he wrote how he and his companions "had been filled with wonder at what they saw and said to each other that all seemed to be like the enchantments written about in Amadis of Gaul * * *, for the things they were seeing never had been seen, heard, or ever dreamed of." It is interesting to learn, through Hernandez, that "many trees of a kind of cypress had been raised from seed at Iztapalapa by one of its lords who took infinite pains to have them cultivated for his enjoyment."

In a chapter entitled "Of the gardens in which Montezuma went for recreation" the scholarly Dr. Cervantes de Salazar, who wrote his famous and long-lost Chronicle in Mexico in 1565 and derived his information from the most reliable sources, records as follows:

This great monarch had many pleasancess and spacious gardens with paths and channels for irrigation. These gardens contained only medicinal and aromatic herbs, flowers, native roses, and trees with fragrant blossoms, of which there are many kinds. He ordered his physicians to make experiments with the medicinal herbs and to employ those best known and tried as remedies in healing the ills of the lords of his court. These gardens gave great pleasure to all who visited them on account of the flowers and roses they contained and of the fragrance they gave forth, especially in the mornings and evenings. It was well worth seeing with how much art and delicacy a thousand figures of persons were made by means of leaves and flowers, also the seats, chapels, and the other constructions which so greatly adorned these places.

In these flower gardens Montezuma did not allow any vegetables or fruit to be grown, saying that it was not kingly to cultivate plants for utility or profit in his pleasure. He said that vegetable gardens and orchards were for slaves or merchants. At the same time he owned such, but they were at a distance, and he seldom visited them.

Outside the City of Mexico he had houses in extensive groves of trees surrounded by water so that the game could not escape and he could be certain of his quarry. In these woods there were fountains, rivers, tanks with fish, rabbit warrens, steep high rocks among which were stags, fallow deer,

hares, foxes, wolves, and other similar animals which the Mexican lords hunted much and very often.

Cervantes de Salazar also gives a description of a hunt that the Mexican ruler watched from his richly adorned litter which rested meanwhile on the shoulders of its bearers. It was no doubt thus that he was often carried from his summer palace at the base of the hill of Chapultepec, which was surrounded by a grove of beautiful "ahuehetes" or swamp cypress, past the bas-relief portraits of himself and his predecessors, carved on the rocks, up a broad, winding flight of steps to its summit. From this he could command a panoramic view of incomparable beauty embracing the whole valley of Mexico with its lakes and the snow-capped volcanoes beyond. In 1554 Salazar, in his "Dialogues," relates that on the top of the hill Montezuma had cultivated trees as though it were a garden and that on its steep sides were terraces with other groves of trees and hanging gardens. He explains the choice of such a site for the cultivation of ornamental trees and flowers with the dictum that "Indians preferred hills to plains"; but an important reason was doubtless that the native gardeners had learnt from long experience that many plants thrive best among rocks which not only preserve moisture but also the heat of the sun, which counteracts the chilliness of the night temperature in this high altitude.

The fact, however, that not only Montezuma but, as we shall see, the Lord of Texcoco and the Tarascan rulers built their pleasure gardens on high hills commanding admirable views indicates that they had a fine taste and a true love of nature in all of its manifestations. In this connection it is interesting to recall here that being a high priest as well as "king," it was one of Montezuma's duties to "arise at midnight to observe the north star and its wheel" (the revolving circumpolar constellations), also the Pleiades and other constellations. From their hill gardens the ancient astronomer priests and rulers of Mexico no doubt often contemplated the heavens, watching for the periodical reappearance of the planets and particularly of the planet Venus, which was celebrated by a solemn festival.

There is a deep pathos in the fact that during his captivity Montezuma several times besought Cortés to give him permission to visit those of his pleasantries which were situated within 1 or 2 leagues of his capital, which naturally included the hill garden of Chapultepec. The Conqueror wrote to his Emperor that the permission was never denied; that Montezuma went accompanied by a number of his nobles and lords whom he entertained with banquets and feasting and that he always returned "very gaily and contentedly" to the apartment assigned to him by his captor—an asser-

tion one may be permitted to doubt. Forming a part of Montezuma's city residence was what Cortés describes as "a house less handsome than his palace where he had a very beautiful garden, overlooked by certain balconies or watch towers, the stone facings and floorings of which were of jasper, very finely worked * * *."

We also know that in the temple precincts flowers were cultivated and that there were "exquisite flower gardens of different kinds on the upper as well as on the lower stories" of the houses of those inhabitants, whom Cortés describes as "vassal lords" and the "wealthy citizens" of the capital. At the Peñon, a rocky hill north of the city where a hot spring wells up, Montezuma had another pleasure. The orchard he owned near Coyoacan was given later by Cortés to Doña Marina, who had acted as interpreter for the conquerors.

The most wonderful of all Montezuma's gardens, however, was the tropical one at Huaxtepec, which he had inherited from his predecessor and namesake, Montezuma the Elder. The native historians relate that the latter, soon after his accession to power about 1450, was reminded by his brother of the garden of their ancestors at Huaxtepec in the tropical region south of the Valley of Mexico, "where there were rocks with carved effigies of his forefathers, rocks, fountains, gardens, trees with flowers, and trees yielding fruit." He thereupon sent thither his principal overseer, named Pinotetl, with orders to inspect and restore the fountains and springs, the streams, reservoirs, and irrigation system. Simultaneously he dispatched messengers to the tropical coast region with a request to the Lord of Cuetlaxtla for plants with roots of the vanilla orchid, of the cacao and magnolia trees, and other valuable vegetable products. With foresight he also asked that these be brought carefully by native gardeners from the same region, capable of replanting them at the proper season and tending them in the customary way. On receiving his message the Lord of Cuetlaxtla immediately gave orders to have a number of all kinds of plants dug up with their roots inclosed in earth, and with exquisite courtesy he had these bundles wrapped in beautiful woven mantles and dispatched to Mexico. The ceremonial observed by the gardeners who accompanied them before planting the trees, etc., "around the fountains in the garden" is worth recording here. They fasted for eight days and, drawing blood from the helix of their ears, they anointed the plants therewith. Asking Pinotetl for a quantity of incense, rubber, and paper, they also made a great sacrifice to the god of flowers, offering him many dead quail after having sprinkled the plants and the soil around them with their blood. They assured the people that after observing these ceremonies none of the plants would be lost and that they would soon bear flowers and fruits.

Their prediction was fulfilled and before three years had passed all of their charges blossomed so luxuriantly that the gardeners from Cuertlaxtla were amazed and said that even in their native soil such plants never flowered so soon. They concluded therefore that the Huaxtepec region suited these valuable plants better than their original home. It is interesting to learn that "then Montezuma lifted his hands to heaven and thanked the God of all creation for these blessings and he and his brothers shed tears of joy at the success of their experiment. For they esteemed as a special mercy and benefit bestowed upon them by the Lord of the Heavens, of the Day and Night, that they could now bequeath to the Mexican people and to all the inhabitants of the Province of Huaxtepec the joy of possessing the precious plants they had been obliged to do without until then."

It was of the Huaxtepec garden that in his letter to Charles V, dated May 15, 1522, Cortés wrote that "it was the finest, pleasantest, and largest that ever was seen, having a circumference of 2 leagues." He adds: "A very pretty rivulet with high banks ran through it from one end to the other. For the distance of two shots from a crossbow there were arbors and refreshing gardens and an infinite number of different kinds of fruit trees; many herbs and sweet-scented flowers. It certainly filled one with admiration to see the grandeur and exquisite beauty of this entire orchard." Other Conquistadores were equally enthusiastic. In his account of Cortés's second expedition, Bernal Diaz wrote: "We went * * * to Huaxtepec where is the pleasure garden * * * which is the finest I have seen in all my life. When Cortés and the Treasurer Alderete saw it and promenaded in it for a while they were filled with admiration and said that even in Spain they had never seen a finer kind of pleasure garden."

Bernal Diaz also records that on his expedition to the hot lands Capt. Gonzalo de Sandoval rested and slept overnight in the Huaxtepec orchard and pronounced it to be "the most beautiful he had seen in New Spain. It contained a greater number of buildings and many more admirable sights than any other garden. Although he had not finished exploring all of it, as it was more than a quarter of a league in length, he considered it certainly to be a pleasure garden worthy of a great prince."

The historian Torquemada, quoting from original sources, supplements the foregoing descriptions by the information that besides groves of trees, rest houses, and gardens full of flowers, fruit, and game there were also plantations and fountains and "several large rocks on which were bowers and oratories and observatories, with the steps leading to them cut in the solid rock."

Doctor Hernandez, the Spanish physician who visited "the royal gardens at Huaxtepec" between 1570 and 1577, mentions two valuable medicinal trees he had seen there, namely the "Brazilwood" (*Caesalpinia crista*), which had been brought thither from Panuco

on the Gulf of Mexico, and a tree belonging to the Bombacaceæ, which was evidently the curious macpalxochitlquauitl, or hand-flower tree (*Chiranthodendron pentadactylon*) which has always been prized by the Mexicans for the uncanny simulacrum of a small red hand produced by the union at the base of its five protruding stamens, and for its tonic effect on the heart.

At the present day it shares the popularity of the yoloxochitl, or heart flower (*Talauma mexicana*) as a sovereign heart remedy, and both figure in the "Farmacopea Mexicana" and can be bought in a dried condition in every market place. The fruit trees which flourished in the famous tropical orchard were probably different kinds of the ahuacatl = avocado (*Persea americana*); of the tzapotl (*Calocarpum mammosum*); the texocotl (*Crataegus*), a species of medlar which makes delicious preserves; the xalxocotl = guava; the macaxocotl (*Spondias mombin*, the "hog plum"); and the capolin (*Prunus capuli*). Among the ornamental trees and shrubs were doubtless the tree now known to botanists as *Bombax ellipticum* and other species of the family; the two poinsettias; the *Gynandropsis speciosa*; the fragrant *Turpinia insignis*; and several acacias, to say nothing of aralias, yuccas, and tree ferns and palms.

Among the showy flowers were the Tigridias, the bulbs of which yield a farinaceous food; marigolds (*Tagetes*) of many kinds, and various species of the orchid, zinnia, cactus, amaryllis, bouvardia, solanum, lantana, bromelia, convolvulus, salvia, and dahlia families; the *Hibiscus spiralis*, the *Solandra guttata* with countless creepers; possibly the tall showy huauhtli (*Amaranthus leucocarpus*) and the *Chenopodium nuttalliae*, the seeds of both of which furnished favorite foods.

After reading the authentic evidence that has been presented one can but reecho the conclusion expressed shortly after the Conquest by Salazar, then residing in Mexico, namely, that "few princes and perhaps not one ever possessed pleasure gardens that equaled those of the great lord Montezuma." From his delightful hill garden at Chapultepec, commanding one of the most beautiful views of the world, this flower lover could visit the Iztapalapa pleasance as he traveled in his litter, by easy stages, to the terrestrial paradise at Huaxtepec, containing the choicest products of tropical vegetation in full magnificence and luxuriance, brought together by the unremitting efforts of his forefathers and his own. It is pitiful to relate that at the present day, with the exception of some grand old ahuehetes and the perennial springs of clear water, nothing remains to testify of the former beauty and grandeur of the first tropical botanical garden on the American Continent.

Returning to the valley of Mexico, we will now review what has been written about the gardens at Texcoco, the ancient seat of native

culture which has been termed "The Athens of America," and was the residence of the most interesting personality in the history of ancient Mexico, whose name would be voiced oftener if it were not generally considered as so unpronounceable. Nezahualcoyotl, the law giver, philosopher, and poet king of Texcoco was born in 1403 and died at the age of 71, after a reign of 50 years. Referring the reader to the works of Prescott and Bancroft for the history of his life and an account of the remarkable code of laws he formulated, attention is drawn here only to the interesting fact that, in order to prevent the destruction of forests and woods he prescribed certain limits to the hewers of trees and severely punished their transgression.

A descendent of his, Ixtlilxochitl, relates that Nezahualcoyotl possessed many kinds of gardens, for he had inherited those which pertained to the palaces of his grandfather and father and had also created no less than eight groves and gardens. "These contained sumptuous palaces beside fountains, canals, drains, tanks, baths, and other intricate waterworks; and were planted with many strange and wonderful varieties of flowers and all sorts of trees, brought thither from remote places. He also had five pieces of land near the lake where food plants were cultivated and he always personally superintended their harvest. Each garden was under the special care of men from one of eight provinces, whose services were rendered as a tribute." Another tribute consisted of the tropical flowers required for the use of the palace, which were sent daily from Cuernavaca, at that time subjected to Texcoco.

Doctor Hernandez, writing between 1570 and 1577, records that Nezahualcoyotl had devoted himself to the study of plants and animals and, being unable to have living specimens of many of the tropical species, had pictures of them painted from nature and copied on the walls of his palace. The drawings of exotic plants were so excellent that the Spanish botanist was able to make use of them. He also mentions seeing the remains of the new palaces, gardens, and groves of trees planted by the poet king.

Writing in the middle of the sixteenth century, Friar Motilinia describes as particularly worth seeing the ruins of Nezahualcoyotl's palace "with its inclosed garden containing more than a thousand very large and very beautiful cedar (cypress) trees"; and a second palace with "many gardens and an immense tank or pool. * * *

In 1850 the American diplomat, Brantz Mayer, in his work on Mexico, described the same ancient grove of cypresses, standing in the level plain northwest of Texcoco as "one of the most remarkable relics of the princes and people of the Texcocan monarchy," and gave the following details: "The grove is formed by double rows of gigantic cypresses, about 500 in number, arranged in a

square corresponding with the points of the compass and inclosing an area of about 10 acres. At the northwestern point of this quadrangle another double row of lordly cypresses runs westwardly toward a dyke north of which there is a deep oblong tank neatly walled and filled with water * * *. Along the raised banks and beneath the double line of the majestic trees were the walks and orchards in which Nezahualcoyotl and his courtiers amused themselves * * *." In his charming book "Anahuac," Prof. E. B. Tylor, who visited Mexico in 1856, wrote of the grove (then called the "Bosque del Contador"): "This is a grand square, looking toward the cardinal points and composed of ahuehuetes, grand old deciduous cypresses, many of them 40 feet around and older than the discovery of America."

In her book on Mexico, Miss Susan Hale mentions having seen in 1891 "a magnificent grove of lofty ahuehuetes surrounding a large quadrangle." At the present day, although their ranks are sadly thinned, many of the superb old historical trees exist, furnishing living proof of the grand scale on which the Texcocan king planned his pleasure gardens. A sixteenth century map reveals that at that time not far from the above quadrangle there was another grove in a large circular inclosure. It may have been in imitation of this or in accordance with the native mystical ideas associated with the circle that the king of Atzacapotzalco laid out the beautiful circular grove of ahuehuetes which still exists, marking the site of another bygone pleasance.

The most famous of Nezahualcoyotl's pleasancesses was that on the high conical hill named Texcotzinco, which overlooks a panoramic view of exquisite beauty with the Lake of Texcoco, lying between the verdant plains and the distant mountains beyond it. Pomar relates that here the king had "many different kinds of plants of variegated colors and singular odors; not only those that grow on the spot but also others brought from the Temperate and Tropical Zones." Here again archeological remains corroborate the truth of the native accounts of former splendor, and reveal how, by means of an ingeniously constructed aqueduct and the filling in of an intervening ravine by means of a colossal solid construction, an abundance of water was brought from the neighboring heights, about 3 leagues distant, to a reservoir with walls more than 8 feet high, on the top of the hill, whence it was distributed in all directions by means of stuccoed channels. In 1850 Brantz Mayer verified that "the hill of Texcotzinco is connected with another hill on the east by a tall embankment about 200 feet high, upon whose level tops, which may be crossed by three persons on horseback abreast, are the remains of an ancient aqueduct built of baked clay, the pipes of which are now as perfect as the day they were first laid."



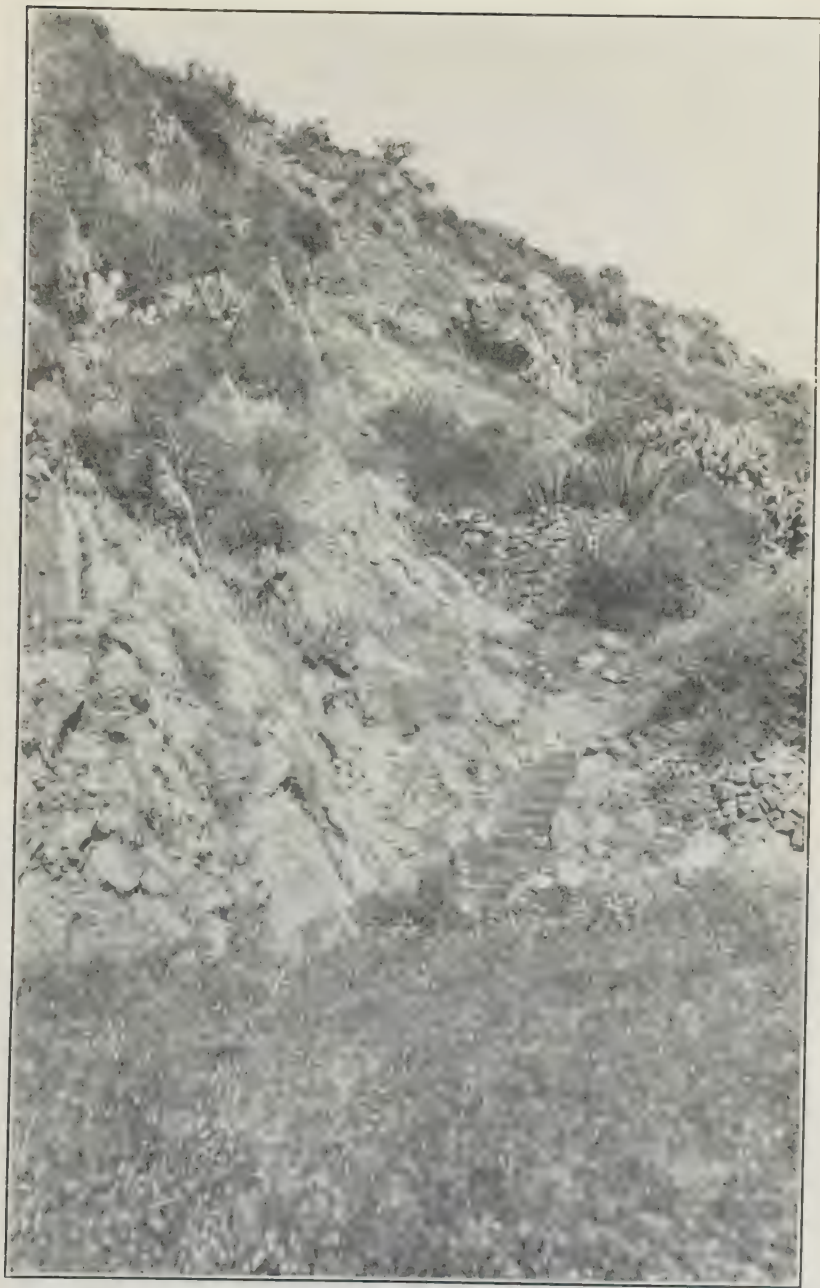
1. GROVE OF ANCIENT AHUEHUETES AT ATZCAPOTZALCO



2. PART OF REMAINING ROW OF AHUEHUETES AT THE "BOSQUE DEL CONTADOR" PLANTED BY NEZAHUALCOYOTL ABOUT 1450



OLD IRRIGATION CANAL ON HILL OF TEXCOTZINCO AND VIEW OF SURROUNDING COUNTRY



VIEW OF TEXCOTZINCO SHOWING PRESENT CONDITION AND REMAINS OF
STAIRS CUT IN SOLID ROCK



VIEW OF XOCHIMILCO CORNFIELDS IN CHINAMPAS

The hill is approached by a gentle slope from the south. Its north side ends abruptly in a precipice which resembles a high wall of rose-colored porphyry. On the crest of the hill are the remains of a small palace and of an edifice with flights of steps which may have led to the famous nine-storied tower described by native historians. There are also vestiges of a building with a well-preserved niche and a platform which may have been an outdoor theater such as those of Tlatelolco and Cholula, described by Spaniards as being of masonry, 13 feet high and 30 paces square, on which arches made of flowers and feathers were erected when performances took place. As during what has been termed "the Golden Age" of "the Athens of America," the poet king had constituted a council of music whose members held sessions and bestowed prizes on the best songs and poems, it is obvious that some suitable stage for the presentation and audition of these must have been provided.

Extremely well preserved are a large circular bathing tank near a stone seat with a high sloping back and a small circular fountain on a platform at the base of a flight of steps, all most skillfully hewn out of the solid and extremely hard rock.

The most remarkable feature of the ruins consists, however, of a circular basin carved in an enormous block of porphyry which projects into space and has been aptly described by the English traveler, W. Bullock, as "standing out like a martin's nest from the side of a house" (see photograph, pl. 3). He also goes on to say: "It is not only an extraordinary bath, but still more extraordinarily placed. It is a beautiful basin about 12 feet long by 8 wide, having a well 5 feet by 4 deep in the center, surrounded by a parapet or rim 2 feet 6 inches high with a throne or chair such as is represented in ancient pictures to have been used by kings. There are steps to descend into the basin or bath, the whole cut out of the living porphyry rock with the most mathematical precision and polished in the most beautiful manner." From the poet king's throne the view is one of surpassing loveliness and includes a view of the City of Mexico 30 miles distant on the opposite shore of the lake. A descendant of Nezahualcoyotl tells of a similar reservoir on the hill from which a stream of water was projected into space and, forming a fine spray, descended like rain on a garden at the base of the hill filled with all kinds of fragrant tropical flowers. A steep flight of steps, now partly preserved, led from the projecting rock to the base of the hill which was "surrounded by a garden in which was planted a diversity of trees and scented flowers. It also contained a number of different kinds of birds beside those the king had in cages brought from distant places, whose songs were so loud that people could not hear each other talk."

It is recorded that the poet king, who had the gift of friendship, not only composed an ode on the death of one of his relatives but had an inscription carved on the breastwork of the stone steps to commemorate the hour, day, month, and year in which the news of the death of the Lord of Huexotzinco, "whom he loved dearly," was brought to him while he was superintending the engineering work on the hill of Texcotzinco. This inscription in hieroglyphics and a number of notable statues and bas-reliefs representing the most important events of the poet king's life were entirely destroyed by order of Archbishop Zumarraga. A richly decorated clay spindle whorl adorned with a swastika, which I found on the hill during my last visit, conjured up visions of the gentle native women who shared the poet's life and his enjoyment of his earthly paradise with its enchanting views, murmuring waters, songs of birds, and all pervading beauty of color and perfume.

In conclusion, an account of the history and true nature of the famous chinampas, or "floating gardens," must be given in order to dispel some of the erroneous ideas concerning them which were first promulgated by the historian Clavijero and have since flourished with a well-known exuberant vitality of error.

In the "Cronica Mexicana" of the native historian Tezozomoc, it is related how at a remote period, after the migratory Nahuas had left Tula, they went southward and reached Tequixquiac. There they manufactured beds (for cultivating food plants), giving them the name of chinamitl. This work signifies literally "an inclosed bed surrounded by a fence made of cane or stakes." the name chinampa is therefore composed of the word for inclosure and the affix pan-pani, which conveys the meaning that the inclosed bed was a raised one, being "on or above the surface." It would seem that these first chinampas were made in a plain, for Tezozomoc makes special mention of the fact that later, when they reached Xaltocan, they "made beds *in the lagoon* and planted seeds of maize, beans, huauhtli (*Amaranthus*), squashes, tomatoes, and chile peppers."

Years later, having reached the valley of Mexico, they selected a site in the shallow fresh-water lagoon, and under the direction of their high priest cut sods of the reeds and other grasses growing in the water and used these to make a foundation for the mud beds they built up, inside of a staked-off inclosure, by means of layer after layer of the muddy sediment at the bottom of the lake. It is exactly in the same way that new chinampas are made nowadays in the Lake of Xochimilco by the descendants of the ancient agriculturalists who, on account of their use of such beds, were and are known as chinampanecas = "chinampa people."

From time immemorial, however, their oblong raised plots, the size of which varies between 20 to 100 feet in length and 7 to 40 feet in

width, have not only been staked off with the thick native cane but have been surrounded by rows of a species of willow the growth of which resembles that of a Lombardy poplar. These willows, being constantly pruned, give little or no shade, and their root growth is phenomenal. With a certain amount of training their interlacing roots form a sort of basketwork which retains the banks of the "chinampas," the age of which can be estimated by their height, which varies between 2 and 8 feet.

Since the water hyacinth (*Eichhornia crassipes*) has been introduced in comparatively recent times, it has been found very useful in building up the chinampas, being spread in thick layers which are allowed to partly dry and partly decay and are then covered with layers of mud. Every year the process of raising the surface of the bed is repeated in order to counteract the erosion produced by the torrential rains in the wet season. By means of a canvas scoop fastened to the crossed end of a pole mud is dredged and cast upon the beds from the bottom of the innumerable small canals which lie between the "chinampas" and have also to be kept in a navigable condition. The same scoops are used by the Indians standing in their punts to cast water in the high, narrow "chinampas" when irrigation is required. The low "chinampas" need no irrigation, but in the wet season run the risk of inundation.

For countless centuries the inhabitants of the capital have been almost entirely supplied with vegetables, maize, and flowers by the industrious "chinampa" gardeners, who manage generally to raise in a year several different successive crops on their artificial plots of land.²

The foregoing data will suffice to establish that it is erroneous to refer to chinampas as "floating gardens."

Ancient Mexican history furnishes, however, instances of true "floating gardens" having actually been made and conveyed from one place to another. The old native accounts of these repeated by Spanish and other historians gave rise to the mistaken idea that it was and is customary for the Mexicans to make and cultivate crops on movable rafts; a method which the shallowness of the water would render impracticable, all water traffic in the canals being carried on by means of punts and small dugout canoes.

In the native chronicles several versions are given of how, during a period corresponding to A. D. 1350-1400, the King of Atzacotzalco and his confederates permitted the newly arrived Nahuas, or Mexicans, to establish themselves in the lagoon and to make and

² An important item of sale is that of young plants of annuals which are raised in a peculiar way. Inside of a raised rim, on a substratum of decayed vegetation, a layer of liquid mud, between 6 and 7 inches deep, is poured and allowed to dry partially. Seedlings are transplanted and set out at equal distances in this bed. When well rooted and grown the bed is well watered and divided into equal squares by cutting lines in the mud with a knife. When half dry each square, with its single plant, whose roots are securely encased in the mud, is lifted out, the compact neat block being easily handled and packed and buried in the garden beds, where the plants flourish rapidly.

cultivate their "chinampas." They exacted from them, however, "as a token of gratitude and subjection, a tribute of vegetables, fish, frogs, and other products of the lagoon." After some years, angered because the newcomers had presumed to elect a ruler of their own, the King of Atzcapotzalco decided to demand an additional tribute, the rendering of which he thought well-nigh impossible.

His messengers informed the settlers that beside the customary tribute they were henceforth to furnish, firstly, grown willow and juniper trees for planting in his capital as an embellishment. Secondly, they were to manufacture a raft on top of which they were to plant all native vegetables and then bring it by water to Atzcapotzalco. The chronicle records that the Mexicans were filled with consternation and grief at so unheard of a demand, but during the night their tribal god appeared to one of their elders and told him to be of good cheer for he would lend aid in making the raft. To the amazement of the King of Atzcapotzalco, who declared the feat "almost supernatural," they actually delivered not only the trees but the floating raft garden full of flourishing food plants and flowers.

Summoning the Mexicans to his palace, he addressed them as follows: "Brethren, it appears to me that you are powerful and that all things are easy to you. It is therefore my wish that in future when you pay your tribute you are to bring on the raft, among the growing vegetables, which are to be in perfect condition, a duck and a heron, each sitting on her eggs. You are to time it so that on arriving here the eggs will hatch. If these conditions are not fulfilled the penalty will be death."

Again the tribal god came to the rescue and the extraordinary tribute was punctually delivered for 50 years, by the end of which time the Mexicans had become powerful enough to cast off their yoke and bondage. From the foregoing it is evident that, as another native historian remarks, the making of "floating gardens" was always considered "an almost impossible and most laborious performance" and was entirely exceptional. The memory of the tyrannically exacted tribute and its payment has, however, been kept alive through the intervening centuries, and as a feature of the water pageants and festivals held on the Viga Canal in viceregal and modern times has often been a simulacrum of a "floating garden," countenance has been lent to the popular, absurd, idea that the chinampas were also "floating" and could be towed at will from place to place.

After reading in the preceding pages of the beauty of the vanished gardens of ancient Mexico, the reader will doubtless share the writer's regret that, at the present time, there is no botanical garden in Mexico or elsewhere containing a representative collection of the wonderful native flora which furnished so much delight to countless generations of the earliest American flower garden lovers.

THE HOVENWEEP NATIONAL MONUMENT

By J. WALTER FEWKES

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[With 10 plates]

INTRODUCTION

There is one and only one locality in the Union where four States come together at a common point. That locality is known as Four Corners, and the four States that adjoin are Colorado, Utah, New Mexico, and Arizona. It is situated in one of the most instructive areas, archeologically speaking, in the Union, for taking it as a center, a circle drawn from it 100 miles in diameter includes some of the largest and most attractive ruins of pre-Columbian United States. Four Corners is situated geographically nearest the heart of that area from which the pueblos sprung, the land of the mythic Sipapu. The massive pueblos of the Chaco Canyon, the cliff dwellings of the Mesa Verde, and the mysterious habitations of the Canyon de Tsay (Chelly) are within this region. The adjoining areas of southwestern Colorado and southeastern Utah are dotted with most interesting relics of a people that has disappeared, and almost everywhere one turns are monumental indications of a pre-Columbian civilization antedating the advent of white men and reaching back to a time before documentary history began.

The zealous Catholic missionaries, Escalante and Dominguez, the first explorers of Colorado, passed through this region in 1776, in their trip from Santa Fe into the untrodden north country, far west of the present city of Dolores, after crossing the river which even then bore that name. They knew nothing of the great ruins on the Mesa Verde, but made a brief reference to one of the ruins in southwestern Colorado. These mounds remained a century longer before they were made known to science by Prof. W. H. Holmes and Mr. W. H. Jackson, members of the Hayden expedition. In 1876 they announced the discovery of towers in the McElmo and Yellow-jacket Canyons, and thus opened a new page in our history. At that time there were few white settlers in this region; the Ute Indians were in possession, and towns like Mancos, Cortez, and Dolores were not settled. Even then the most magnificent of all our cliff dwellings were unknown. Of those on the Mesa Verde, Cliff Palace

and Spruce-tree House were discovered in 1883, and Sun Temple was first made known in 1915 and Fire House a few years later. The settlement of the Montezuma Valley by a white population revealed many other monuments of the past in this region, not the least striking of which were towers and great houses along the McElmo and the tributaries of the Yellowjacket, and finally the more instructive of these, preserved and protected, were called the Hovenweep National Monument.

ITINERARY

This monument is at present more or less isolated and difficult to approach, as the roads are not of the best. Two roads are available to visit it, one from Dolores, the other from Mancos, Colo., by way of Cortez. The Dolores road crosses the Dolores River shortly after leaving that city and continues westward, following approximately the old Spanish trail past a modern reservoir, Siguaro, a large pile of stones marking the oldest described pueblo of the region. The course of the road is to Dove Creek and Monticello, but at Sandstone post office a branch to the left, known as the Old Bluff City road, but little used, leads to the reserve called the Hovenweep Monument. One advantage of this road over another to the south by way of Cortez is that there are no streams to cross and no quicksands to endanger the traveler. The distance from Dolores is about 45 miles, and that by the McElmo Canyon road a little longer. The Yellowjacket is a treacherous stream, especially after rains, and is avoided by wise travelers in the rainy season. There is no regular hotel on either route, but water is found along the McElmo, and a place to sleep at a store called the McElmo post office. Prosperous farmers are settled along both* routes, and the melons, cantaloupes, and fruit of the McElmo have a wide reputation.

To the Hovenweep and back is a strenuous trip for one day, but it can be made. Should the tourist decide to visit Cannon Ball Ruin he will find it best to sleep at McElmo post office, where meals are served.

The road to the Hovenweep Monument through the McElmo Canyon is more picturesque than that from Dolores. The two roads have a common terminus, and it is better to go by one route and return by the other. The McElmo or southern route takes one from Mancos, Colo., to Cortez, part of the way the same as that to the Mesa Verde National Park, the branch to which is indicated by a conspicuous signboard. For several miles the Mesa Verde is visible on the left and the road climbing the precipitous cliff is observed very plainly.

THE HOVENWEEP NATIONAL MONUMENT¹

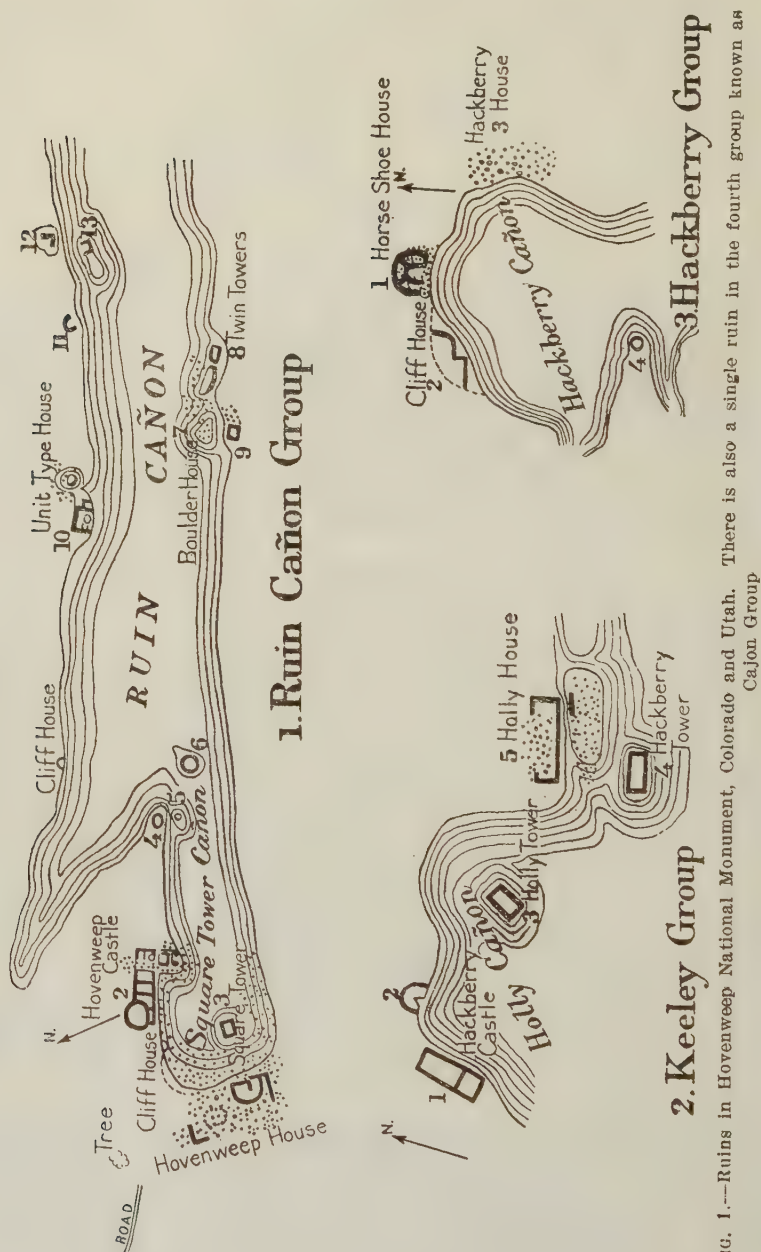
On March 2, 1923, the late President Harding issued a proclamation creating a new monument in southwestern Colorado and southeastern Utah. Like several others, this reserve was created for the preservation of its antiquities which, although having the same general character as those of the adjacent Mesa Verde National Park, are somewhat different. The special kind of ruins characteristic of the Hovenweep monument are well preserved towers, similar to those which are found in the Mesa Verde National Park, and are most abundant and varied in the country west of that plateau far into Utah. Archeologically speaking this monument supplements the Mesa Verde National Park and the structure of its towers and other buildings explains some of the enigmas of ruins in the park. As this new reservation was created to preserve its numerous towers, a brief notice of a few buildings of the same type would be a fitting introduction to those of the new national monument. Fortunately the author's field work during the summer of 1922 renders it possible to interpret some of the architectural features of the new monument.

There are several towers on the Mesa Verde that are like those of the new monument, showing that the prehistoric people of the Hovenweep resembled those of the Mesa Verde.

Three types of prehistoric towers are found in our Southwest: (1) Square, circular, or semicircular towers without surrounding rooms; (2) towers accompanied with basal subterranean ceremonial rooms or kivas; (3) towers rising from pueblos or cliff dwellings. The first type of tower is generally mounted on top of a pinnacle of rock or on the rim of a canyon. The second type is situated on level ground or earth that allows excavation of basal kivas, and the third rises from a pueblo or cliff house in which there are both kivas and living rooms. The relatively greater abundance of the second type, or a tower with a basal ceremonial room and no dwellings, would seem to indicate that the tower was connected with ceremonies, and if this be true it also seems likely that when associated with a number of rooms, as in a large ruin like Cliff Palace, it preserved the same character.

Several theories have been suggested to explain the function of southwestern towers. They have been regarded as observatories, forts, bins for the storage of grain, especially corn, and as inclosures for the performance of religious rites. There are indi-

¹ Reprinted by permission from the *American Anthropologist*, Vol. 25, No. 2, April-June, 1923.



cations that they were built by an agricultural people, one of the primal necessities of whom is to determine the time for planting. This can be obtained by observations of the sun's rising and setting, and a tower affords the elevation necessary for that purpose; hence the theory that southwestern towers were in part used for sun houses or observatories. A building from which the aboriginal priests determined calendric events by solar observations very naturally became a room for sun worship or for the worship of the power of the sky.

The presence of circular subterranean rooms, which almost always occur with towers, also indicates religious rites. As the tower may have been devoted to the worship of father sun or the sky god, in the underground kiva may have been celebrated the rites of mother earth. The rooms at the base of the tower in which kivas are embedded, in towers of the third type, indicate habitations and necessary granaries, as well as rooms for ceremonials. In support of the interpretation that some of these rooms are granaries, we find rows of vases in which corn is stored still standing in them.

Pipe Shrine House, on Mesa Verde, excavated by the author during the summer of 1922, presents a good example of the third type, for in it we have the tower, the sunken kiva, and the rectangular basal rooms. The ceremonial character of this building is shown not only by the tower and kiva, but also by many shrines in which formerly stood stone idols of the serpent, the mountain lion, the mountain sheep, or other objects of worship. On the northeast corner of the ruin near an inclosure there was found a stone slab on which the sun was depicted, indicating that this building may have been used for sun-worship rites, and a coiled pictograph of a large serpent carved on the south wall likewise points to this worship. The evidence indicates that this building was constructed for rites and ceremonies of the sun and earth deities, and the tower and its accompanying subterranean room in cliff houses indicate that the ancient priests of Mesa Verde worshipped the two great nature principles, father sky and mother earth, which dominate the ritual of every agricultural people.

The new reservation, called the Hovenweep² National Monument (fig. 1), contains several towers in a much better state of preservation than any in the Mesa Verde, a condition which indicates that they were constructed later. The ruined castles and towers of this monument are among the best preserved aboriginal buildings in the

² The name Hovenweep, which has been given to this monument, is taken from the Ute language and has been translated "Deserted Valley." It is now applied to a tributary of the Yellowjacket, but was originally the name of the main canyon.

Southwest. The reservation (fig. 2) includes four groups of ruins, now called Ruin Canyon, Keeley, Hackberry, and Cajon.

There are 13 ruins in the Ruin Canyon group, over half of which are towers of the second type, which have kivas at their bases. One of the largest ruins is in Square Tower Canyon and stands at the head of the canyon, rising from the very rim. Although sections of the walls of this building have fallen, the remains of a large semi-

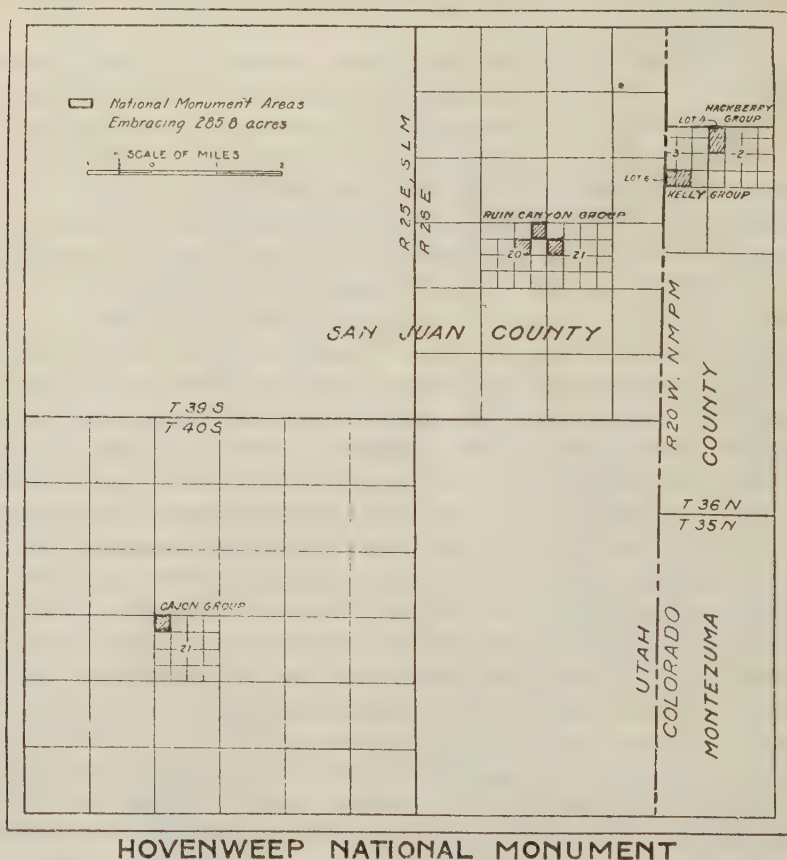


FIG. 2.—Hovenweep National Monument

circular house are conspicuous for some distance. This ruin also has buried kivas surrounded by square or rectangular rooms. In the midst of walls there formerly rose a conspicuous multichambered tower, whose foundation is D-shaped, its straight wall measuring 23 and the curved 56 feet. The northeast corner rises 15 feet high, and the walls of the northwest angle of the ruin are still higher. This ruin, called Hovenweep House, resembles somewhat Far View House on the Mesa Verde National Park.

HOVENWEEP HOUSE

This building (pl. 1, fig. 1) was a pueblo that stood on the canyon rim at the head of Square Tower Canyon. Most of its walls have now fallen into the canyon and are strewn around on the mesa, forming an unsightly mound; but there still remain sections of standing walls of fine masonry rising out of the mound, which are visible as conspicuous structures as one approaches the cluster of prehistoric dwellings that compose a part of Hovenweep House. Under the cliff below it are remains of a very large cliff dwelling, the walls of which are dilapidated, although still preserving certain architectural features. These walls could be protected at very small expense and would present a fine type of cliff-dwellers' masonry. Near by, below Square Tower, stands another tower, one of the best examples of this type of building in the Southwest. It rises from the top of a pinnacle, on a well-preserved foundation on all four sides. This building has given the name of Square Tower Canyon to the southern fork of Ruin Canyon. Although tall, its summit is not high enough to afford a view very far down the canyon. The north and south forks of Ruin Canyon are separated from each other by a tongue of land ending in a precipice, on which are remnants of a tower having a magnificent outlook. This structure presents some of the best masonry in the Southwest. At the base of the precipice, as if guarding its entrance to Square Tower Canyon from the approach of hostile people, are ruins 5 and 6, which are worthy of exploration by the archeologist. Ruin 5 stands on a large angular boulder, with what appears to be an opening or doorway on the north side. An instructive architectural feature of tower 5 consists of two parallel walls, apparently characteristic of this small ruin, one on each side of this doorway.

* There are situated on the north rim of Ruin Canyon three interesting structures. One of these is known as Unit Type House (pl. 1, fig. 2) from the fact that it consists of a single circular kiva of well-made masonry around which are arranged six rooms. The southern wall of this ruin is more or less broken down, and the eastern portion also shows signs of destruction, but on the northeast corner there is a remnant of a room so dilapidated that it can not well be made out. Ruin 11 is composed of a cluster of small buildings, and ruin 13, called Stronghold House (pl. 2, fig. 2), is one of the most picturesque ruins of the monument. The best ruins in Ruin Canyon, however, are on the south rim, numbered 8 and 9 on the accompanying map. Number 7, known as Eroded Boulder House (pl. 3, fig. 1), is mainly remarkable for its site. Perched on top of an eroded boulder, there stands a tower, while the rooms

are on the northeastern side. The mortar is fresh in the walls of the latter, and the marks of human hands can readily be seen. There are one or two places in which a corncob is still found embedded in the adobe, and indentations of corncobs used by the plasterers are still visible. At the base of Boulder House there are many fallen walls extending down the canyon. Ruin 9 (pl. 2, fig. 1), the ground plan of which is rectangular, stands about 11 feet high on the south rim of the canyon. A doorway opens in the middle of its north wall and is so arranged as to make it difficult to enter. The masonry in ruin 9 is rough, and projecting ends of rafters indicate that it was formerly two stories high. A short distance from the foundation is a stone cairn which was once used as a shrine.

Perhaps the most remarkable ruins in Ruin Canyon are the so-called Twin Towers (pl. 3, fig. 2), which are so closely approximated that from certain points they look like one ruin. They are situated on the south side of the canyon, covering the top of a rock isolated from the rim of the mesa by a deep cleft. The foundation of the larger of the twins is oval and in the southwest corner is a doorway; the smaller tower is horseshoe shaped. The arrangement of rooms inside both towers, as shown in the ground plan, is regular, one wall conforming to the outline of the towers. The walled-up caves below the bases of these towers are small and apparently used for storage. The Square Tower cluster and a few smaller ruins near it are designated on the map by the name Ruin Canyon Group. These towers are situated in Utah, not far from the boundary between San Juan County and Montezuma County. There is no water near this cluster. One or two additional towers may be seen by following down the canyon, which eventually discharges its water into the Yellowjacket.

Most of the walls of the Keeley group of ruins are well preserved. The cluster is situated about a small canyon and is approached on foot from Keeley Camp, where there is a constant spring of good water. Two of the Keeley ruins belong to the tower type and are built on boulders.

The largest ruin in this vicinity, called Hackberry Castle, is rectangular in form and stands on the edge of the canyon. There are rafters in the wall at a level about 12 feet above the base. A second ruin, a short distance north of Hackberry Castle, also rises from the rim of the canyon. Its walls are well preserved and the outline of the base about square, with corners rounded. There are indications that the entrance to this room was through the floor.

Two other towers in the bottom of the canyon show some of the finest masonry of this region. Their foundations cover the top of

fallen boulders, which rise to a considerable height. The well-made doorways are wide above and narrow below. The approach at present is difficult on account of the height of the basal rock on which the ruin stands. There are evidences that the former inhabitants used foot holes cut in the base in order to enter this building.

The third group of ruins, known as the Hackberry group, has several well-preserved prehistoric stone buildings. Hackberry Canyon is one of the terminal spurs of Bridge Canyon. The main ruin in this cluster is called, from its ground plan, the Horseshoe House (pl. 4, fig. 1). It is particularly instructive from the fact that it has a central circular tower which is for two-thirds of its circumference concentric with the outer wall, to which it is united by radial partitions. It is situated on the north edge of the canyon, with its straight wall on the south side. The northeastern corner of Horseshoe House stands several feet higher than the southeast, which corner rests on a projecting rock, reminding one of the cornerstone of Sun Temple. The masonry of most of the southern segment of the inclosed circular inner wall has fallen down the cliff. There apparently was no doorway on this south side, as the line of wall is so near the cliff. The ruin is not large, the south wall being about 30 feet in length and the highest wall about 12 feet. A short distance north of Horseshoe House there are two large pueblos in a ruined tower rising from an extensive pueblo whose walls have fallen. At the foot of the cliff on which Horseshoe House stands is a cliff house with a single kiva (pl. 4, fig. 2).

The best preserved building in the Hovenweep National Monument, called Hovenweep Castle (pl. 5, fig. 1), is divided into two sections, western and southern, imparting to the ground plan of the ruin the shape of the letter L. It has towers and kivas arranged about rectangular rooms; and the western end is composed of a massive-walled semicircular tower and well-preserved rooms with high walls.

The eastern section, like the western, has a tower and circular depressions or kivas. On the north and south ends this section rises into high walls inclosing rectangular rooms, those at the north end being better constructed, and standing as high as the walls of the western tower. The corners of these buildings, as is generally the case, are not well preserved, due to lack of properly tying or binding the courses of masonry. Much débris has accumulated in and around the kivas, filling their cavities; it is evident that these ceremonial rooms were formerly one-storied, and practically are subterranean on account of the height of surrounding rooms. Fragments of standing walls project out of the accumulated débris, indicating rooms at the junction of the eastern and western sections of

the ruin, but the form and arrangement of walls at that junction are not evident. The walls of one of the kivas show evidences of mural pilasters and banquettes like those of cliff dwellings.

The fourth group of ruins in the Hovenweep Monument is situated at the head of a small canyon on the Cajon Mesa a few miles west of those already described. To the largest ruin of this group, the author has given the name Cool Spring House (pl. 5, fig. 2), on account of the fine drinking water in the canyon below it. This ruin would well repay extensive study and contains features not yet described in other ruins.⁴

POTTERY AND OTHER OBJECTS

Through the kindness of Mr. Williamson, cashier of the national bank at Dolores, the author is able to give a brief chapter on pottery and other objects from the neighborhood of Hovenweep National Monument. In a general way the architecture of the buildings in the Hovenweep National Monument is identical with that of the buildings on top of the Mesa Verde and likewise the buildings in the intervening areas separating the two. The large mounds in the Montezuma Valley west of the Mesa Verde have such a close likeness to those in the Mummy Lake group and elsewhere on the surface of the Mesa Verde Park that we may suppose their former buildings identical in culture. Wherever we find true cliff dwellings in this vast area we have evidence of cultural similarities. In other words the architectural types of the Mesa are practically duplications of those in the neighboring valleys, and the conclusion is evident that all this neighborhood was formerly inhabited by a widespread people in a similar stage of development. The extent of the distribution of these similarities, north, west, south, and east, is a most interesting problem for the archeologist to solve, for it indicates the horizontal spread of a characteristic culture.

But similarity in architectural features is only one means by which the archeologist recognizes the extension of culture; another is the similarity in form, colors, and designs of pottery. An examination of ceramic objects reveals the fact that there is no radical difference in pottery throughout this area and we find by comparison that pottery from the Hovenweep National Monument is so similar to that from the Mesa Verde that one may say it is identical, and is the product of people in the same cultural stage. The ceramic evidence thus supports the architectural that the former inhabitants of the Hovenweep National Monument were the same as those of the Mesa Verde. But it must be borne in mind that we are handicapped by the paucity of specimens from the two regions for com-

⁴ For further details of Bull. 70, Bur. Amer. Ethn., and Smithsonian Misc. Coll., Vol. 68, No. 1, 1917.

parative purposes and uncertainty as to the localities from which individual specimens were taken. We know that the pottery figured in the following pages came from the valleys adjoining the Mesa Verde on the west, far enough down the San Juan River to establish the fact that the area peopled by Indians who made the same pottery was a large one.

There are only a few collections from the area we are now considering and nothing of note from the Hovenweep National Monument, but the author had the good fortune to examine a few small collections found in the McElmo and tributary canyons and in the ruins in Montezuma Valley, the majority of which were found in the neighborhood of the Hovenweep National Monument and in mounds situated in Montezuma County. A collection known as the Williamson collection, gathered in this area, was exhibited for many years in the First National Bank at Dolores, and through the kindness of Mr. Williamson the author was able to take photographs and make a few drawings of the most striking specimens. There are many relics besides pottery, but the most abundant type belongs to the ceramic group called black and white or gray ware with black designs. This ware belongs to the most flourishing epoch of cliff dwellers. Figures of typical forms are shown in the following illustrations:

Plate 6, Figures 1 and 2, represent drinking mugs, the former specimen closely allied to those from the Montezuma Valley and the Mesa Verde. The essential character of mugs from the Mesa Verde area, both on the plateau and the valley at its base, is the enlarged base, which always has a greater diameter than the opening. The decoration on this mug (pl. 6, fig. 1) is made up of black triangles arranged in four series and divided into pairs separated by an encircling band. The handle extends from the lip to the base—a characteristic design—but in this particular specimen has no decoration. This mug was found at the source of the McElmo⁵ Canyon, possibly at the three-walled tower at Mud Creek. Another mug (pl. 6, fig. 2), in which the diameters of the lip and the base are about equal, has its surface decorated in two zones separated by an encircling band. The decorations in these two bands consist of terraced figures separated by a zigzag white line shown in Plate 6, Figure 2. There were several other mugs in the collection, but all have the same general character. The remarkable similarity of these mugs to those found in the Mesa Verde cliff houses is strong evidence that the culture of the Indians who lived in the

⁵ A settler calls this the McElmen Canyon, from an old resident of that name.

cliff houses and in the pueblos or open villages in the plain was identical.

Two specimens of jugs made of black and white ware are figured in Plate 6, Figures 3, 4. These specimens are made of rough ware ornamented by the simplest geometrical patterns; one of these has simply encircling black bands. The handle arises above the neck and continues to the middle of the jug. These objects are flattened at the base, but otherwise similar to those from the Mesa Verde region so often described.

Plate 6, Figures 5 and 6, and Plate 7, Figure 2, show globular vases with small mouth openings. They belong to the group of white or gray ware decorated with black designs. The two lugs suggest that these objects are canteens, having at the base of the neck two knobs or mounted disks which no doubt served for the adjustment, to which were attached strings by means of which they could be carried over the shoulder. The two figures represent the same canteen from different sides.

One of the most remarkable globular jugs (pl. 7, fig. 1) in the Williamson collection is four-lobed at the base and decorated with hatchure and circles each with a central black spot. The handle of this jug is marked with parallel black lines.

There is in the Williamson collection an effigy bowl in the form of a bird, here shown (pl. 7, figs. 3 and 4) from side and top. One interesting feature brought out in this effigy bowl is the T-shaped opening on the back and the striated representation of the wings.

Another type, approaching in form the bird effigy already considered, is a clipper-shaped vessel shown in Plate 7, Figure 5, which has no indication of a head or wings but should be classified near the bird effigies.

Plate 7, Figure 7, represents a duck-shaped effigy vase with lateral ridges indicating the position of wings. The handle has been broken. This object is made of rough ware, unornamented.

In 1922 the author found at Pipe Shrine House, in the Mesa Verde National Park, a similar bird effigy to that figured in Plate 7, Figures 3 and 4, which also has a well-made head and a T-shaped opening in the back.

An exceptional form of ceramic ware which was found at the crossing of the river at Dolores is shown in Plate 7, Figure 6. This object is a globular, undecorated vessel, unlike any form that has thus far been recorded from the Mesa Verde.

Plate 7, Figures 8 and 9, represents a clay specimen of three cups united. It belongs to the gray ware; the bottoms of all are flat; sides rounded.

The remarkable triangular vase shown in Plate 8, Figure 7, has two extensions, one on each side of the terminal opening. The surface of this strange form, whose use is unknown, is decorated with parallel lines arranged symmetrically.

Among the modern Hopi the feather plays such an important part in their ceremonial system that it is customary for every priest to have a box for feathers, which in old times was made of a root of the cottonwood. The object (pl. 8, figs. 2 and 4) indicates that the ancients of the Montezuma Valley also had a feather box of similar shape but made of clay. Although this receptacle is much smaller than the feather box of the modern Hopi, it served an identical purpose.

Food basins (pl. 8, figs. 5 and 6) in the Williamson collection from the area in which Hovenweep Monument is situated are very rudely decorated with geometrical figures and mainly belong to the black and white ware. They resemble those of the Mesa Verde National Park. Plate 8, Figure 6, has the rim decorated.

Thus far very few fetishes have been found in the Mesa Verde region, but two good specimens from the valley are shown in Plate 8, Figures 1 and 3, side and front views. These objects are made of marble and are perforated, suggesting that they were worn on the person as pendants of necklaces or other ornaments. It is possible that they were used as fetishes for aid in hunting, much as the Pueblos employ similar figurines at the present day.

The most exceptional form of pottery is shown in Plate 9, Figures 1 and 2. This is a double vase consisting of two almost globular vessels united by a rude effigy of an unknown animal. This twin vessel is made of white ware with a simple geometrical decoration in black. It was evidently a ceremonial object in which possibly sacred water was carried.

CONCLUSIONS

It is almost impossible to traverse the country surrounding the Hovenweep Monument without observing mounds and other remnants of the former housebuilders. The remarkable similarity of these remains is everywhere apparent. It is unnecessary to excavate any considerable number of these mounds to prove the identity of the builders. Neither is it desirable or necessary to reserve the extensive tracts of land upon which they stand to preserve the type of buildings characteristic of the extensive culture area to which they belong. The Hovenweep National Monument contains buildings typical of an extended area in southwestern Colorado, southeastern Utah, New Mexico, and Arizona. Similar buildings of the same type are found as far north as the Dinosaur beds of Utah and

follow down the San Juan to an indefinite horizon. In the south the culture they represent merges into the Chaco Canyon region and that of the pueblos on the Rio Grande.

The relationship of Hovenweep buildings to those on the Mesa Verde is practically identical, but there are forms of buildings in the Hovenweep country which have not yet been found on the Mesa Verde. The massive character of the walls of several typical buildings of the Hovenweep suggests solidity and construction necessary for defense, and these buildings are ordinarily situated on the edges of great canyons and may have been so placed to secure distance views down the canyons or extensive vistas over the waterless plains. Plate 10 shows a tower on a projecting rock which has fallen and probably buried a cave dwelling. The masonry of the great houses is the most massive of all those made by the inhabitants of the San Juan drainage. In addition to this feature, attention may be called to the predominance of the tower element, which is likewise a Mesa Verde characteristic. They are condensed in form, not spread over a large area. The closest of the Hovenweep likenesses to the Mesa Verde buildings is the ceremonial rooms known as kivas, which are seen in Unit Type House, wherein we have a single central circular room surrounded by square rooms, very similar to the One Clan House near the road from Mancos to Spruce-tree House. The terraced form of building so common among modern pueblos and so well illustrated in Far View House on the Mesa Verde has not thus far been made out clearly in pueblos of the Hovenweep Monument, nor do we find clusters of disjoined small buildings indicating a pueblo in process of formation so common in Hovenweep Monument as at Mesa Verde. This indicates to the writer's mind that the unconsolidated units of the Mesa Verde pueblos are older than the more closely amalgamated pueblos of the Hovenweep or the still more compact Chaco pueblos. It is apparent, as no evidence of white habitation has been found, that all are strictly pre-Columbian buildings; and their fine preservation would indicate that they are more modern than the mounds which conceal similar buildings on the Mesa Verde.

As we go west from Hovenweep there is a gradual change in architectural types and a corresponding change in relative age of the monumental remains. While stone houses whose walls are not very unlike those of the Hovenweep occur in this far western region, there is an older appearance to the ruins and a closer affinity to a prepuebloan type which on the Mesa Verde underlies the puebloan. In the Hovenweep Monument there are evidences of two epochs of culture, an early earth lodge or pit dwelling culture and a later epoch, the buildings of which were constructed upon the more ancient. This underlying

prepuebloan culture, generally extinct or submerged by a new influx of pueblo buildings, may have been an early stage in the evolution or a local development. The later or pueblo form, being more complex, varies more in different regions, although derived from an almost identical prepuebloan type. It is not possible from our limited knowledge to make any final statement regarding the age of these two types of culture or the causes that led to the final abandonment of these buildings. The same reasons that have been advanced for the desertion of the Mesa Verde habitations are no doubt valid for those of the Hovenweep; migrations due to pressure produced by inroads of hostiles; desire for better farms and more water; changes of climate, perhaps; even growth of local feuds among different settlements, due to congestion of population, may have contributed to the migration of the Hovenweep people. The traces of direction of migration shown by the distribution of buildings suggest a southern migration or toward the sun, where farming conditions were more favorable and inroads of hostile people less frequent. Legends current among the pueblos support this conclusion. The population of this region was fairly large, or at any rate the size of the houses, with a few notable exceptions, indicate this. The people could not have had very extensive knowledge of where they were going, and there is no evidence of their possessing beasts of burden or other modes of transportation over long distances. Their struggle for physical existence was fierce, their migratory movement slow, and the evidences are that they harvested fairly good crops for a limited time as they spread over the country. The desire to improve their condition was intensified by the growth of population. Of necessity they sought the river valleys where water was constant and always available, and those unoccupied fields that were fertile were more extensive than any that could be found in a rocky environment.

Absolutely nothing of the speech of these people is known with certainty. Their language may have been assimilated with some pueblo stock to the south, but with which group we have no means of knowing. Not a single one of their place names survives, so far as researches have gone. No systematic study of somatological data is available to teach the affinities of these people. Their age is unknown and the explanation of why they left their homes is merged into the general history of the conquests of sedentary people in our Southwest and that of our more vigorous incoming tribes. The Tanoan Indians have several place names, which are mentioned by Harrington and others.

The most important conclusions arrived at by a comparative study of architecture and material culture is that the Hovenweep people were of the same race as those that built the great houses and

towers of the Mesa Verde. Within the area in which lie these two Government reservations we find evidences of two distinct modes of life; a simple one in which there was one clan in one house, and another in which multiple clans inhabited one or more united houses; the one an earth-lodge people, the other a pueblo people. The pueblo phase of house construction was of local growth; the earth lodge, having a wider distribution, would appear to have been antecedent to this local differentiation into multiroom pueblos, and hence is called the prepuebloan, but is supposed to survive in so far as architecture goes among nonpueblo tribes like the Navajos in the pueblo area.

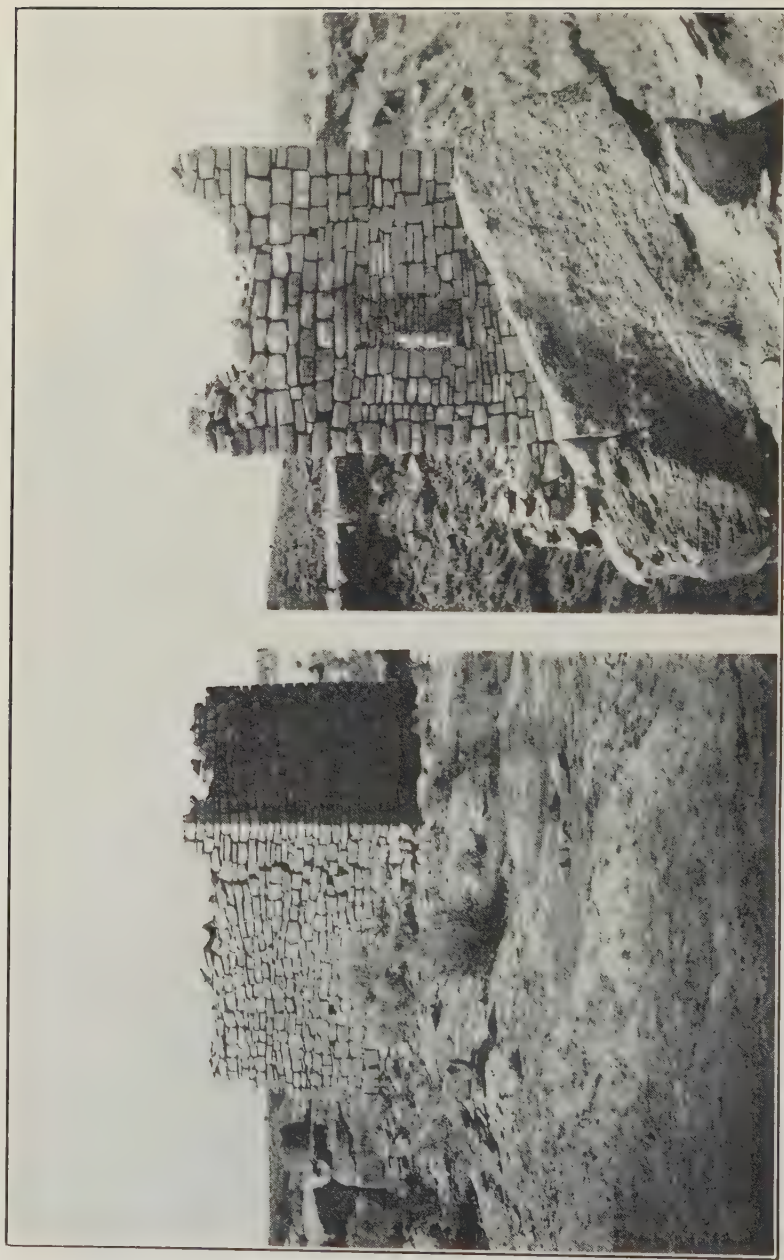
The Hovenweep National Monument thus gives us an example of typical prehistoric stone buildings situated west of the Mesa Verde having an allied culture, but showing certain variations that are significant. None of the towers shows any signs of having been made or used by the white man.



1. HOVENWEEP HOUSE AND HOVENWEEP CASTLE, HOVENWEEP NATIONAL MONUMENT



2. UNIT TYPE HOUSE, HOVENWEEP NATIONAL MONUMENT



I. RUIN 9

2. STRONGHOLD HOUSE



1. ERODED BOWLDER HOUSE (INDICATED BY ARROW). UNIT TYPE HOUSE IS SHOWN ON THE RIGHT AND TWIN TOWERS ON THE LEFT

Courtesy of Denver & Rio Grande Railroad. G. L. Beam, photographer



2. TWIN TOWERS, FROM CANYON, HOVENWEEP NATIONAL MONUMENT



1. HORSESHOE HOUSE, HOVENWEEP NATIONAL MONUMENT



2. CLIFF HOUSE UNDER HORSESHOE HOUSE, HOVENWEEP NATIONAL MONUMENT

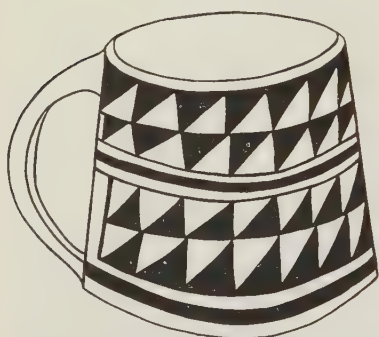
(Wirsula, photographer)



1. HOVENWEEP CASTLE, RUIN CANYON GROUP, HOVENWEEP NATIONAL MONUMENT



2. COOL SPRING HOUSE, CAJON GROUP, HOVENWEEP NATIONAL MONUMENT



1



2



3



4



5



6

CERAMIC OBJECTS FOUND NEAR DOLORES, SOUTHWESTERN COLORADO.
BLACK AND WHITE WARE. WILLIAMSON COLLECTION



1



2



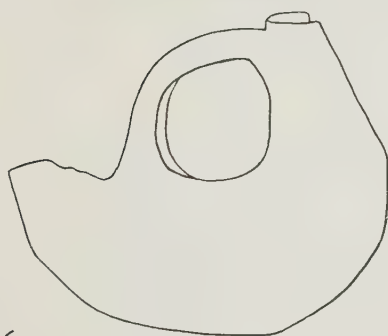
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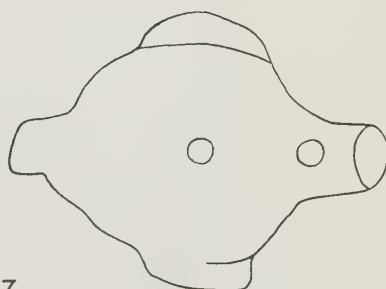
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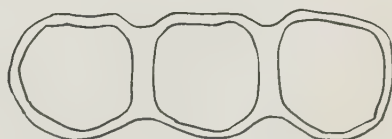
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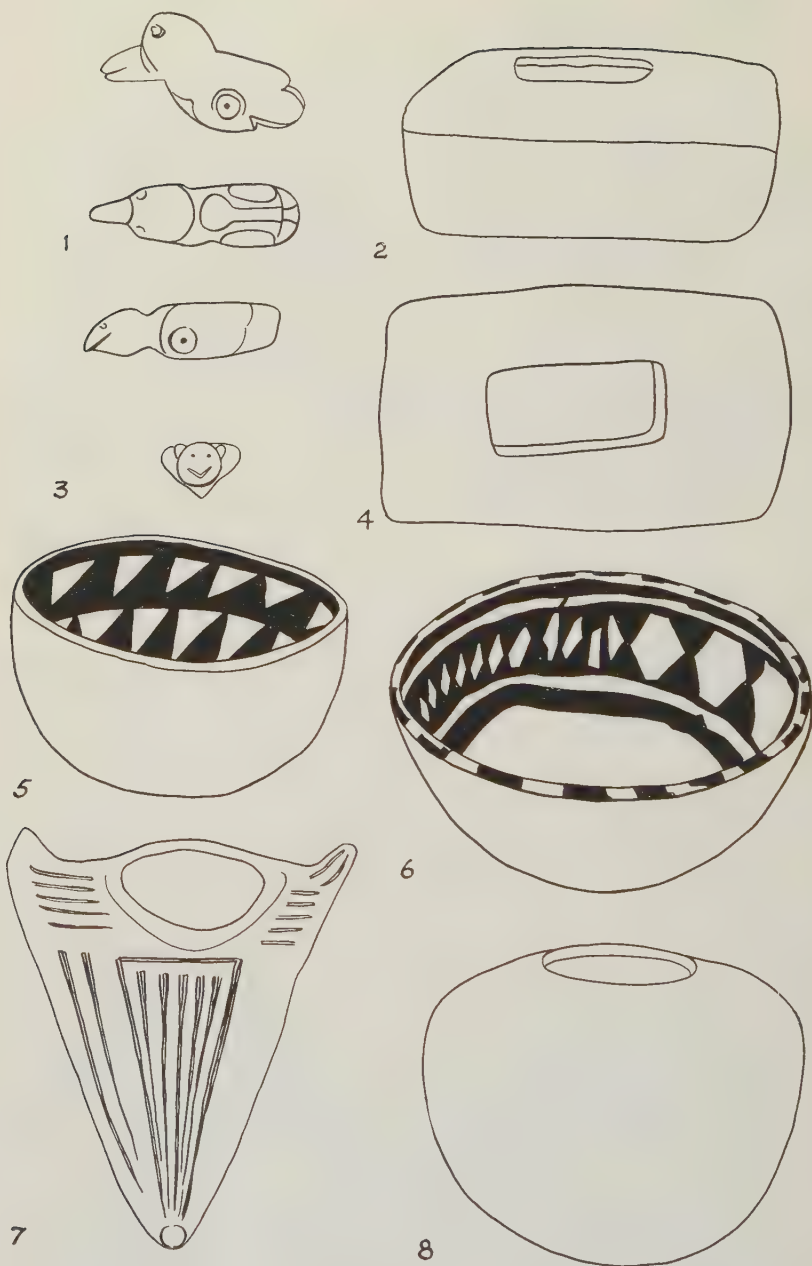


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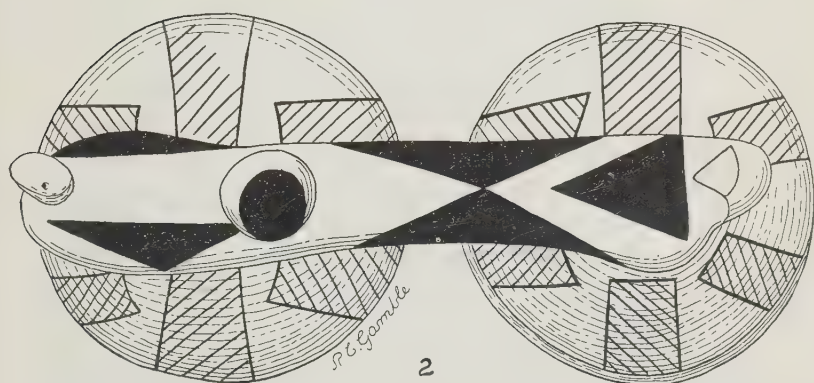
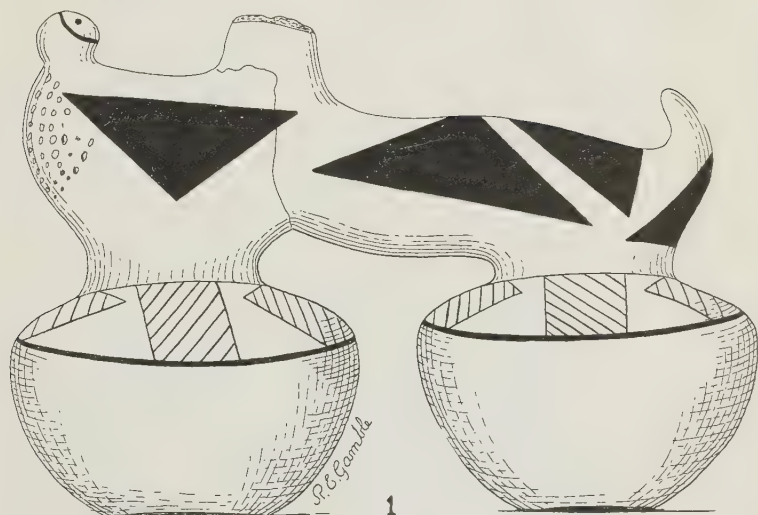


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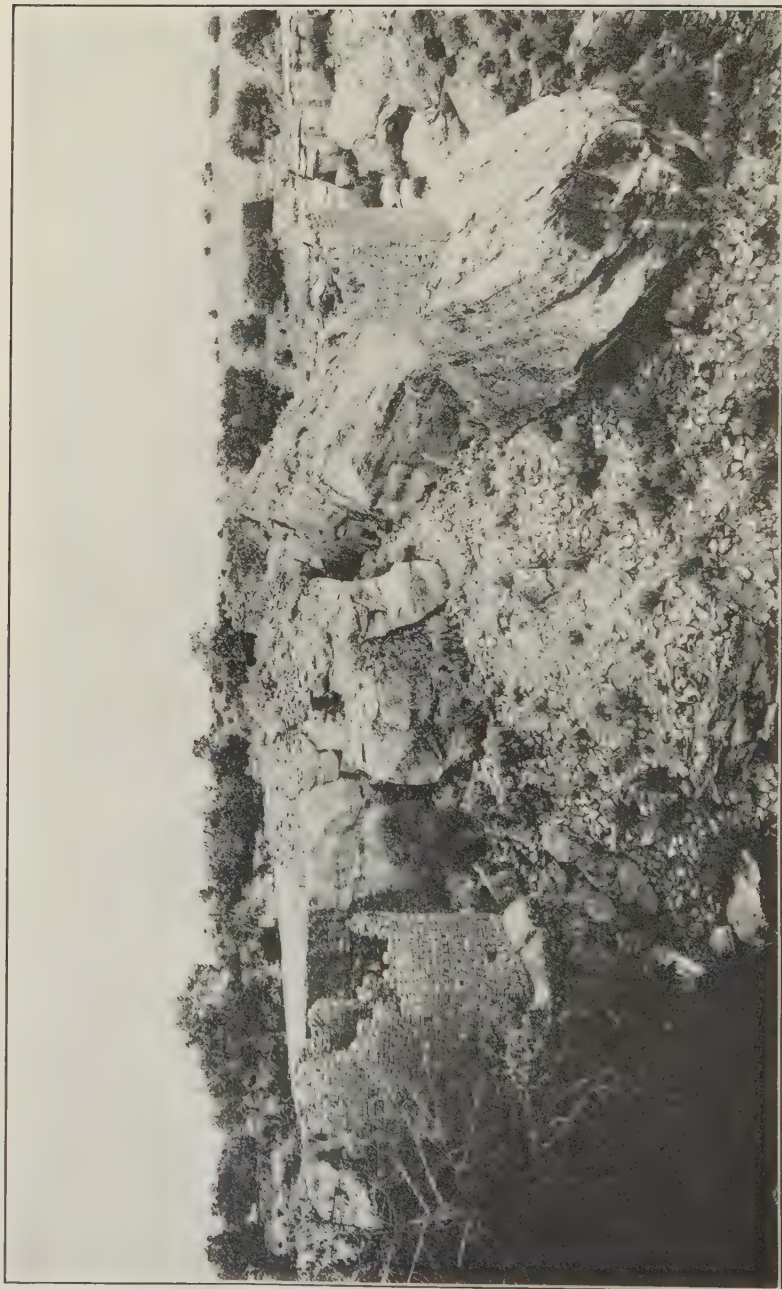
CERAMIC OBJECTS FOUND NEAR DOLORES, SOUTHWESTERN COLORADO. WILLIAMSON COLLECTION. 1, LOBULAR VESSEL; 2, SMALL VASE; 3, 4, BIRD-SHAPED VESSEL; 5, 6, 7, BIRD EFFIGY VESSELS; 8, 9, SMALL POTTERY OBJECT WITH THREE COMPARTMENTS



AMULETS AND POTTERY FROM SOUTHWESTERN COLORADO, FOUND NEAR DOLORES. 1, 3, DIFFERENT VIEWS OF STONE FETISHES; 2, 4, POTTERY FEATHER BOX; 5-8, POTTERY OBJECTS OF BLACK AND WHITE WARE



DOUBLE-BOWLED CEREMONIAL VESSEL IN FORM OF A COMPOSITE ANIMAL.
BLACK AND WHITE WARE. FROM SOUTHWESTERN COLORADO, NEAR
DOLORES



FALLEN ROCK WITH PUEBLO AND TOWER, HOLLY CANYON
Courtesy of Denver & Rio Grande Railroad. G. L. Beam, photographer

THE ORIGIN AND ANTIQUITY OF THE AMERICAN INDIAN ¹

By ALEŠ HRDLÍČKA

[With 17 plates]

The great problem of American prehistory is that of the genesis of the Indians, who when first seen by white men were already spread over the entire American continent as well as all its habitable islands.

Without discussing the many older speculations on the subject, we will approach directly the several concrete questions into which this problem resolves itself. The foremost of these is that of the race unity or plurality of the Indians.

It is known that the aboriginal population of America was divided into many tribes, and even a number of what might be called nations, often hostile to one another; we have learned that there were many different languages and dialects, remarkable differences in culture and the material results of culture, and also marked differences in the physiognomy, color, stature, head form, details of physique, and in the general behavior of the different groups of Indians—all of which would seem to indicate that there might have existed here some, if not considerable, racial diversity.

But if these matters are subjected to careful and comprehensive scrutiny, we find that the various differences presented by the Indians are often more apparent than real; that actual and important differences are in no case of sufficient weight to permit of any radical dissociation on that basis; and that the more substantial differences which exist between the tribes are everywhere underlaid by fundamental similarities and identities that outweigh them and that speak strongly not only against any plurality of race on the American continent, taking the term *race* in its fullest meaning, but for the general original unity of the Indians.

We thus see that the American *languages*, while not infrequently differing greatly in phonetics, vocabulary, and even structure, belong nevertheless to one fundamental large class—the polysynthetic—and present other important resemblances in their com-

¹ Rewritten for the Annual Report of the Smithsonian Institution from "The Genesis of the American Indian," Proc. XIX Intern. Cong. Americanists, Washington, 1917, 559-568.

plexity of grammar, ideas of gender, formation of numerals, modes of plurality, formation and rôle of prefixes and suffixes, relative values of the pronoun, dialectic differences in the two sexes, etc., which, taken together, speak for one and the same (though doubtless ancient and probably extra-American) broad parentage.

In a similar way we find that, notwithstanding numerous more or less pronounced local differences in detail, there are in all tribes many deep-seated and significant evidences of a similar *culture*. They exist in the stone, clay, wood, and bone technique; in weaving and basketry; in methods of housing, of fire making; in clothing and the limited household furniture; in agriculture; in games; in all that relates to medicine, religion, conceptions of nature; in folklore; in social organizations; in the usages of war; and in still other important and intimate phases of Indian life.

Going still further, there are found essential resemblances in the *mind* and *behavior* of the Indians throughout the two continents. One who has become well acquainted with the mentality of the natives in any region of either North America or South America, will find, on eliminating the local environmental peculiarities, faithful counterparts in all other regions; and the behavior of the Indian is in substance much the same everywhere in his family and tribal relations, in the care of the young, in all his functions, in his ceremonies, songs, warfare, in his peculiarities.

The *constitution* of the Indian, using the term in its modern medical sense, is also much the same throughout the two continents. He is everywhere readily affected by, and falls an easy prey to alcohol; he is physically enduring, without in general being actually exceptionally strong; he is little if at all, subject to various degenerating and constitutional diseases such as cretinism, rachitis, cancer, insanity, etc., but is everywhere readily affected by tuberculosis, trachoma, measles, smallpox, and syphilis.

Last, but not least, there are, notwithstanding certain differences, the basic resemblances and identities of his body and skeleton. Some of these features are:

1. The Indian's color differs, according to localities and habits, from dusky yellowish, or brownish yellow, through all shades of brown, to that of solid chocolate; but the fundamental color is moderate brown, or yellowish-brown.

2. The hair, as a rule, is black (to reddish-black after exposure); it ranges about to above medium in coarseness, being never fine; and it is straight, except in the old or unkept, where there may be slight irregular waviness, and in the men who wear longer hair, where the ends may show some tendency to turn upward or wave.



KALMUCK BOY

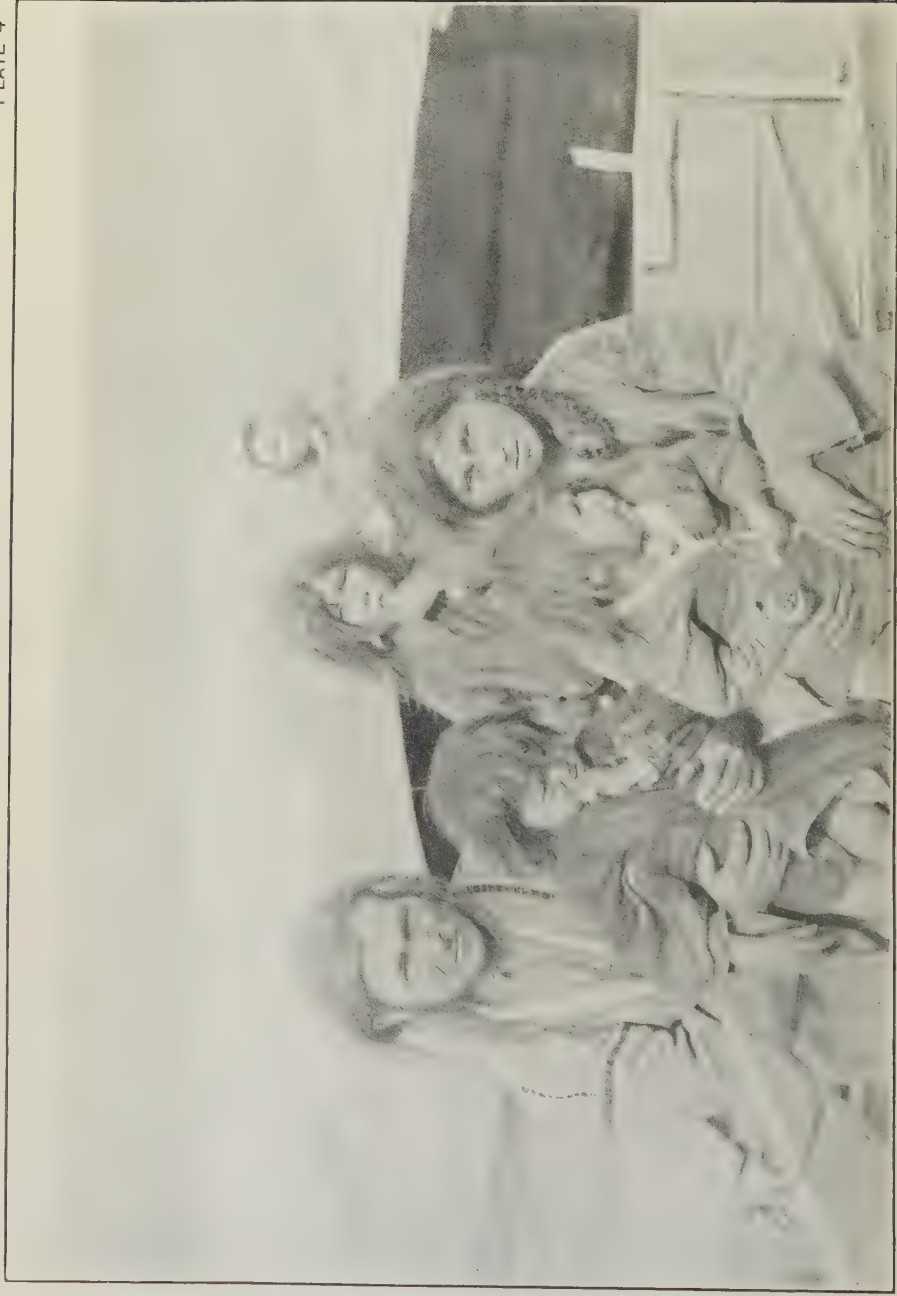


A JURAK-SAMOYED MAN

(After Szombathy)



TWO "TUNGHUZ," SIBERIA
(Russ. Anthropol. Jour.)



A FAMILY OF YENISEI OSTIAKS

(Photograph obtained by the U. S. National Museum through exchange from the Ethnographical and Anthropological Museum of Peter the Great, St. Petersburg)

The beard is more or less scanty, on the sides of the face completely absent, and never long. On the body there is usually no visible hair except perhaps a little in the axillæ, with more on the pubis, though even there it is frequently sparse.

3. The Indian is free from special characteristic odor appreciable to the white man. His normal heart-beat is slow. His other physiological functions are everywhere much alike. The size of the head and of the brain cavity, though differing considerably in individuals and with the mean stature, averages on the whole slightly less than that of white men and women of similar height. The skull is in general slightly thicker and presents many features of the base, etc., that are of the same class all over the continent.

4. Indians' eyes, as a rule, are above medium to dark brown in color, with decidedly bluish conjunctiva in younger children, pearly white in older subjects, dirty-yellowish in adults; and the eye slits show a prevailing tendency, more or less noticeable in different tribes, to a slight or moderate upward slant; that is, the external canthi are frequently more or less appreciably higher than the internal.

5. The nasal bridge is only moderately to fairly well arched; the nose is frequently strongly developed in the males and often convex ("aquiline") in shape, but is lower, shorter, and more commonly straight or even concave in the females. It is never very high nor so fine or slender as in whites, nor again so flat and thick and broad as in the negro; and its relative proportions in the living as well as in the skull (barring individual and some localized exceptions) are prevalently medium or mesorhinic. The malar regions are, as a rule, rather large or prominent. The suborbital or canine fossæ are in general more shallow than in whites. All of which is true throughout the tribes.

6. The mouth is generally fairly large to large, and the same may be said of the palate. The lips average from medium to somewhat fuller than in whites, are never thin (except after loss of front teeth and after alveolar absorption), and never so thick as in the negro; and the lower facial region shows in general a medium degree of prognathism, standing, like the relative proportions of the nose and many other features, about midway between those in the whites and those characteristic of the negroes, though on the whole rather closer to the white. The chin is well developed, but on the average somewhat more voluminous and less prominent than in whites, and is not seldom square. The entire lower jaw is on the average somewhat larger than in whites. The teeth are from medium to above medium size when compared with those of primitive man in general, but perceptibly larger when contrasted with those of the cultured white

American or European; the upper incisors of the Indian present throughout, with infrequent individual exceptions, an especially important feature: They are on the inside, or lingually, characteristically shovel-shaped, that is, deeply and peculiarly concave, with a marked border surrounding the concavity.² The ears are rather large.

7. The neck, as a rule, is of only medium length and never thin in health; the chest is mostly somewhat deeper than in average whites; the breasts of the women are of medium size to somewhat above medium, and often more or less conical in form, the true hemispherical type being a rarity. In the females, the disproportion between the pelvic region and the shoulders is less marked than in American whites. There is an absence of steatopygy; the lumbar curve is moderate. The lower limbs are somewhat less shapely and generally less full than in whites; the calf in the majority is rather slender, more so than in the average whites or negroes.

8. The hands and feet, as a rule, are of relatively moderate dimensions, and what is among the most important distinguishing features of the Indian, the relative proportions of his forearms to arms and those of the distal parts of the lower limbs to the proximal (or, in the skeleton, the radio-humeral and tibio-femoral indices), are in general throughout the two parts of the continent of similar average value, which differs from that of both the whites and the negroes, standing again more or less in an intermediary position.

9. In the Indian skeleton, from Canada to Tierra del Fuego, besides the characteristics hitherto mentioned, point after point of important resemblance or identity are met with which mark unequivocally the many distinct tribes as descendants of one and the same older group of humanity or ancestral stock, and serve to distinguish them from other peoples except those with which they have a common prehistoric origin. Such features include, besides those relating to the skull, such highly distinctive traits as general platybrachy in the humerus, frequent platymery in the femur, and frequent platycnæmy in the tibia; high frequency of perforation of the septum in the humerus; great rarity of the supracondyloid process in any form; and many other conditions. There are tribal or local differences in these respects, but on the whole the similarity of the skeletal parts throughout the continent is such that a classification of the Indians into more than one original race is quite impossible.

Taking all the above facts into consideration, and remembering that whatever differences are observable in the Indians in any direction are equaled if not exceeded in other large fundamental

² See "Shovel-Shaped Teeth." *Am. Jour. Phys. Anthropol.*, Washington, 1920, III, No. 4.

groups of humanity, such as the whites, the Asiatic yellow-browns, and others, there appears the possibility of only one conclusion, which is that the Indians throughout the American continent represent but one strain of humanity, one main race; and that the variations observable in the great group are intraracial fluctuations and developments, of more or less remote, frequently perhaps of pre-American, origin. These variations in some instances may constitute types or subraces, but they go no further, for even in such more specialized strains the majority of the physical as well as the physiological characteristics remain still intimately connected with those of the remainder of the Indians.

Having thus reached the important conclusion of the fundamental unity of the American race, we may now approach the second great question regarding the American aborigines; namely, *the antiquity of the race on this continent*.

The solution of this part of the problem may be approached in two ways: (a) By critical reasoning; and (b) through material evidence.

(a) Can the Indian possibly be regarded as a true autochthon of America? In other words, could he have evolved from lower forms on this continent? There have been those (and they included men of science such as Morton and, more recently, Ameghino) who were inclined to adopt or who actually proclaimed this view. But in the present state of our knowledge it is easy enough to dispose of this hypothesis. The anthropologist of to-day knows definitely that man evolved from the nearer Primates; there is abundant material evidence to that effect, regardless of other considerations. These Primates must naturally have approached man in all important respects, a condition that could be realized only by the most advanced anthropoid apes; but the existence of such forms in America is very doubtful. There were on this continent Eocene and Oligocene lemurs and other primitive forms, and ultimately the ordinary American monkeys, but nothing so far as known of any advanced type that could possibly be included in the more proximate ancestry of man, unless it was the recently described (Osborn, Gregory³) *Hesperopithecus*, which, however, is still represented by an imperfect and badly worn tooth, with another specimen in still worse condition, the identification of which as teeth of a higher anthropoid it is difficult to accept as conclusive. These facts alone suffice to render an American origin of the Indian extremely improbable.

³ Osborn (H. F.) *Hesperopithecus*, etc. Am. Mus. Novitates, No. 37, 1922.

Gregory (Wm. K.) and Milo Hellman. Notes on the molars of *Hesperopithecus* and of *Pithecanthropus*. Bull. Am. Nat. Hist., 1923, XLVIII, Art. 13.

But there are other logical and decisive proofs that such origin was impossible. The two main are as follows:

1. The Indians, notwithstanding their diverse special characteristics, are on the whole exceedingly like the rest of mankind in every important feature, so that if we should accept the view that they originated in America we would practically be obliged to conclude that all mankind originated here—a theory that has actually been advocated but which at the present time would probably seem monstrous even to those who would otherwise be disposed to believe in an American origin of the Indians. For it is well known that all the really known Primate species that come or ever came near to man live or lived in parts of the Old World, and that the earliest known forms of humanity belong equally to the Old World. It is to the warmer regions of the Old World that the best scientific evidence leads us to look for man's origin, and the rest of the earth could have been peopled only through the gradual dispersion of mankind, or of a form that eventually led to mankind, from the Old World center or centers of development.

2. Secondly, we know that a very early and physically as well as culturally very primitive form of humanity had reached the central part of western Europe somewhere before, probably much before, the middle of the Quaternary or Glacial Epoch, and we would look in vain for any feasible mode of bringing such primitive beings at that time from America to what is now southwestern Germany, Belgium, France, Spain, and England.

All these reasonings, nevertheless, would perforce be subverted if, as has happened so frequently within the last few decades in Europe, there were discovered on the American continent unquestionable skeletal or cultural remains of geologically ancient man. As might be expected from the great interest in such remains aroused by the European discoveries, with human credulity and especially the general inclination of less disciplined or trained minds toward the wonderful, with its dwarfs, giants, and beings of mysterious power or of great antiquity, and also as a result the many possibilities of accidental inclusion of human artifacts or remains in old strata, the occasional rapid fossilization of human bones, and a possible comingling of such bones or other vestiges of man with the bones of ancient animals—claims to discoveries of skeletal or other remains of early American man have not been wanting and will not be wanting as time goes on. Announcements of such discoveries have appeared repeatedly both in North America and in South America, and have given rise to much speculation. On being subjected to thorough scientific scrutiny, however, the antiquity of the majority of the finds on which the structure of man's antiquity in America



SIBERIAN NATIVES. THE BABY IS HALF WHITE



OROCZI, KONI RIVER, SIBERIA



TWO MONGOL WOMEN WITH A BOY IN FRONT OF THEIR YURTA, NORTH OF URGA

(Hrdlička, 1912)



MONGOLIAN MAN



A MONGOL, URGА
(Hrdlička, 1912)

was or is to be reared vanish as evidence, and the residue is supported by testimony so indecisive that no conclusion of geological age of the remains can legitimately be based thereon.⁴ Impartially weighed, the probabilities are in every instance against rather than for geological antiquity. So far, then, the subject may be summarized by the statement that, while we now possess numerous and in some instances great anthropological collections from this continent, and while many old caves, rock shelters, and other sites, some of which have yielded remains of Quarternary or earlier animals, have been carefully explored, there is to this day not a single American human bone in existence or on record the geological antiquity of which can be demonstrated beyond doubt. It is in fact impossible for us to produce, though they might reasonably be expected, any specimens that can demonstrably compare in antiquity with the remains of, for instance, the predynastic Egyptians, unless it is the most recently found but not yet definitely determined bones of Los Angeles.⁵

As the question stands, therefore, even if we were inclined to accept man's geological antiquity on this continent on the basis of some a priori consideration (for which, however, there is no adequate ground), we should seek in vain for support of the theory from material evidence; and we can not possibly have recourse to the personal opinions of those who, because of religious beliefs, temperamental inclination, other bias, or imperfect observation, have claimed and in some instances still claim the presence of man here in times far antedating the recent or even the Glacial period.

It stands to reason that if man had originated in America and spread thence to other continents, or if he had come here hundreds or even scores of thousands of years ago, we should by this time have found some evidence of his great local antiquity which could be freely acceptable to all of us, as are the remains of European early man. Wherever man has lived for any length of time, he has invariably left behind him implements, utensils, and refuse containing shells and bones of contemporaneous mollusks, fish, birds, and mammals, with remains of fire. If there is no such evidence, or at least none that the most thorough students of the subject can conscientiously accept, then assuredly we are not justified at the present time in accepting the theory of any geological antiquity of the American race.

⁴ Detailed treatment of this question from various aspects will be found in Bulletins 33, 52, and 66, of the Bureau of American Ethnology. By "Geological age" is meant age greater than that of the recent or postglacial period.

⁵ In a preliminary report on these remains before the National Academy of Science by Dr. John C. Merriam (Apr. 29, 1924), it was shown that they also probably are postglacial and that their age, while doubtless considerable, is to be estimated in thousands, rather than in tens of thousands of years. See *Science*, July 4, 1924.

Having reached the only possible conclusions on the two important questions thus far considered, namely, that the American aborigines represent a single race, and that the presence of this race on this continent is of no demonstrated geological antiquity, we reach the third and final complex of questions involved in the problem of the genesis of the American Indians—the *whence*, *when*, and *how* of his occupancy of the New World.

Considering the primitive means of transportation of prehistoric man, it will be agreed, I think, that he could have come only from those parts of the Old World that lie nearest to America. These portions are the western coast of northern Africa, northwestern Europe, and particularly the northeastern parts of Asia; and geology shows that there were no nearer lands or other than perhaps a far northern (north of Bering Strait) Asiatic-American land connection, within the period that can be assigned to man's existence.

Between Africa and South America, however, at their nearest approach, there are nearly 2,000 miles of distance, and the separation between the nearest points of North America and Europe is even much greater. It is not at all likely, to say the least, that man reached the American continent from either of these directions except since protohistoric times, after he had sufficiently developed a means of navigation, with those of prolonged self-sustenance; and this likelihood would hold equally true if he had come by way of Iceland or Greenland, for even there the ocean stretches are very considerable.

But, turning to the Asiatic continent, we find no such insuperable difficulties. Only about 30 miles separates the two continents at Bering Strait, and in clear weather American land is visible from the hills of the East Cape of Asia. North of Bering Strait there may have existed until relatively recent times an actual land connection over which many animals possibly reached the New World and which could have served as a direct bridge for man, but as yet no direct evidence has been obtained that man could have come at that time. The Bering Sea itself, however, could have been crossed, by way of St. Lawrence Island or even over the open. And much farther south there is the long semilunar chain of the Aleutians which reach to within 400 miles of Kamchatka, and even that distance is broken nearly into halves by the Commander Islands. It is true that the sea here is rough, and fogs prevail, but from what we know of the achievements in navigation by the natives of the northern Pacific coasts, in skin boats, in recent times, it is within the range of possibility that these conditions could have been overcome and the distance covered by men of earlier times. Here, then, we have several practicable routes by which the Asiatics could have reached

America, and their presence, with the absence of other such routes elsewhere, gives strong support to the view that those who eventually became the American aborigines reached this continent from north-eastern Asia.

Let us now turn to racial evidence. We have passed above in brief review the principal physical and physiological characteristics that distinguish the American aborigines. Where, in the Old World, are there or ever were there people who approach this type most closely?

This was surely not in Africa, for there is little in common between the Negro and the Indian. It was not in historic Europe, which, during that time and barring a few Asiatic incursions, was peopled only by the white race. If we turn to Asia, however, we see that large parts of Siberia and the eastern coast of the continent, with much of Malaysia and even Polynesia, were and still are peopled by nations and tribes which differ more or less from one another, owing to admixtures and local differentiation, but which on the whole are of a type that in most of its essentials resembles, or is practically identical with, that of the Indian. This type persists to this day with particular purity in certain parts of the Philippine Islands (such as among the Igorrots), in Formosa, in portions of Tibet, in parts of western China, in Mongolia, and over many parts of Siberia. It can frequently be met with in China proper, in Korea, and in Japan. It is a type which is characterized by the same range of color, as well as the quality and peculiarities of distribution of the hair; by the same dark-brown eyes with yellowish conjunctiva and slight to moderate slant; by similar prominence of the cheek bones and characteristics of other parts of the face; by similar frequency of the hollowed-out upper front teeth; by close resemblance in the rest of the body; and, in addition, by similar mentality and behavior, with close affinities in other functions, as well as in numerous habits and customs. The physical resemblances between some members of the Asiatic groups and the average American Indian are such that if a member of one or the other were transplanted and his body and hair dressed like those of the tribe in the midst of which he was placed, he could not possibly be distinguished physically by any means at the command of even a scientific observer.

Such resemblances can not possibly be fortuitous. They show that eastern Asia has been and in large measure still is peopled by a type of humanity which, while no more homogenous than for example the white race, stands nevertheless on the whole nearest of all the human types to that of the American aborigines. Given the close proximity of the two continents, which would permit the passage from one to the other of people even in a relatively primitive state

of culture; and finding that, outside of heterogeneous immigrants and mixtures, the two regions are peopled to this day by radically the same type of humanity, there is the strongest possible argument for the unity of origin of the eastern Asiatics and the American Indians. And as man can scarcely be assumed to have originated in America and to have migrated to Asia, there remains the one possible conclusion that the American aborigines were derived from the Asiatic continent; and they must have come by the northern routes, which were not only the most practicable but were the only ones that would enable man in the earlier stages of culture to reach the New World. The Pacific islands were not peopled until relatively recent times, later than America itself, and hence need not be considered in this connection any more than historic Europe or Africa. If any parties of these islanders ever reached the American continent, which is not impossible, they could have come only after the Indians had spread over it and were well established, and while such parties could have introduced perhaps a few cultural peculiarities, they could not materially have affected the population.

Granting, on the basis of the above considerations, that the American aborigines came originally from Asia, we are still confronted by the two important questions as to when and how this immigration could have been effected.

As to the *time*, there is no direct evidence and none can be hoped for. Yet it seems that in an indirect way we may approach a solution of this mooted question.

It is self-evident that before man could have migrated from Asia he must have peopled that continent; and he must have peopled it in relatively large numbers, for only that would have enabled him to overrun such an immense territory. Man does not migrate like birds—he spreads. He is gregarious, and he is a creature of habits, one of the strongest of which is attachment to his home, whether the limited site of a sedentary community or the larger territory of a nomad tribe. He will move only because of compulsion, such as may be caused by enemies, some calamity, or the exhaustion of resources; or because of better prospects ahead in the way of climate or food. He can not be supposed to have reached the colder north-eastern limits of Asia before the warmer, richer, or more available parts of that continent were settled or hunted over; and he could not have reached America, of course, before all this took place. We are able then to establish one definite landmark in reference to the time of the beginning of the peopling of America; it could only have followed that of Asia.

This leads to the second step in our quest, namely, the peopling of Asia itself, and more particularly of its northern portions.



A MONGOL, URGА

(Hrdlička, 1912)



A MONGOL, URGU

(Hrdlička, 1912)



A BUNUN MAN OF FORMOSA



Archeological researches in northern Asia, including Japan and China, are still in their beginning, nevertheless they indicate the presence, over a wide territory, of many remains of human occupancy, in the form of burial mounds and of ruins, with other signs of man's activity. The great majority of these remains are known to be of no great antiquity, dating from historic or late prehistoric times; but there are also older mounds, cave remains, and dwelling sites which yield only stone and bone implements, and primitive pottery. These latter remains are the earliest in eastern and northeastern Asia thus far discovered, and the culture they represent corresponds generally to that of parts of the Neolithic epoch of Europe. And what is true of cultural applies also to the skeletal remains from these sites—they show relatively modern forms, much like those that existed in the Old World during the neolithic age. We have therefore no evidence, or even a promise of evidence, so far, that these farther portions of the Asiatic continent were peopled except at a relatively recent period. It is true that Paleolithic implements occur in a certain region along the Yenisei River in Siberia, and that others have been found lately in northwestern China, but these finds, even if they should prove to represent a fairly ancient man, are thousands of miles away from where man could have eventually crossed over to America. All this leads to the strong presumption that the beginning of migration into America did not take place before the time of the European late Paleolithic or earlier Neolithic period, which, reduced to years, would be somewhere between possibly ten or at most fifteen thousands of years ago and the dawn of the proto-historic period in the Old World.

Here, however, the claim might be urged that perhaps northern Asiatic man had a different origin from the European Neolithic population, and may have reached the northern confines of Asia before the more westerly branch or branches of humanity peopled most of Europe. To this it may be answered that it would be merely a hypothesis unsupported by any material evidence. The northern Asiatic man of all periods is too near in every important respect to the white man to be regarded as a distant relative, much less as a different species, as he would necessarily be if he had a separate origin; and there is nothing that would even suggest his presence in northeastern Asia before the existence of late Paleolithic or Neolithic man of Europe. It seems much more justifiable to accept the view that he was derived from the same stock as the European Pre-neolithic and Neolithic population, and that he peopled Asia through migration by the central and southern routes. But granting, for the sake of argument, the wholly improbable supposition that he had developed apart in or to the south of Asia, we would still have to as-

sume that, having reached a physical and cultural status practically identical with the later prehistoric European, and having spread over about as much territory as he would have covered in coming from Europe or Asia Minor, and that really in the face of greater obstacles, his advent in the northeastern limits of the Asiatic continent could not have been any earlier than it would have been had he started from the west and passed over the great central steppes. The assumption, therefore, of a separate origin of the north Asiatic and consequently the American man from that of the European, would not make the Indian any more ancient.

Thus, from whatsoever aspect we take the question, the *when* of the peopling of America does not yield to answer except in terms of moderate antiquity corresponding in all probability with that of the late Paleolithic to Neolithic Europeans.⁶

It remains for us to give thought to the *mode* or *modes* of man's advent into the New World and his subsequent spread and multiplication on this continent.

Here it is necessary, in the first place, to free ourselves from all notion of mass migration. The northeastern portions of the Asiatic Continent were never fit within man's time either to harbor or to permit the migration of any large number of human beings at one time.

The only rational conclusion in this connection seems to be the following: The northeastern Asiatic man in relatively small nomadic or seminomadic groups hunted and fished along the rivers and sea-coast, living in proximity. As game diminished through this hunting or from other causes, he followed it, not southward, where other tribes were doubtless already established, but farther northward and eastward, in the direction of least resistance and of greater abundance, until he reached the Kuriles, Kamchatka, and finally the northeastern extremity of Asia. Before arriving at the limits of the mainland he was doubtless already well provided with and expert in the use of boats capable under favorable circumstances of making prolonged sea voyages. Some party then may have struck out or was driven eastward, reaching the Aleutian chain. Once discovered, these islands would serve as a natural bridge, over which in the course of time groups of Siberian natives could reach Alaska and the American Continent. Or a party first crossed by way of Bering Strait, or possibly by the still more northerly land connection, if it existed. Doubtless in the course of time the Asiatic native utilized all the practicable means of ingress to the New World. Once on the American Continent, of better climate, full of game, and

⁶ Compare writer's "The Peopling of Asia." Proc. Am. Philos. Soc., 1921, LX, 535, et seq.

free of people, they would not turn back, unless to bring their families and fellows, but would follow the game, spread rapidly and multiply rapidly, and under favoring conditions it would not have taken a great many centuries to people both North America and South America.

At all events, whatever the exact circumstances of the first peopling of the American Continent may have been, it may be safely assumed that only relatively small parties reached the new land at one time, and that there was no migration in mass, no flow of whole peoples. But such comings were doubtless repeated; the news of the new land must have reached those left behind and farther, so that the first parties would be followed soon by others, irregularly in all probability, and on the whole very slowly, but interminably. Quite likely there were even various rediscoveries of the New World in different parts of its northwestern limits, and the dribbling over may be assumed to have continued from the time the first Asiatic parties reached the new land to the historic period, when parties of Eskimo were found to trade across St. Lawrence Island and Bering Strait.

The newcomers, though all belonging to the same main race, were evidently not strictly homogeneous, but represented several distinct subtypes of the yellow-brown people, with differences in culture and language.

The first of these subtypes to come over was, according to many indications, the dolichocephalic Indian, represented in North America to-day by the great Algonquian, Iroquois, Siouan, and Shoshonean stocks; farther south by the Piman-Aztec Tribes; and in South America by many branches extending over large parts of that continent from Venezuela and the coast of Brazil to Tierra del Fuego. The so-called "Lagoa Santa race" were merely Indians of this type.

Next came, it seems, what Morton called the "Toltec" type, quite as Indian as the other, but marked by brachycephaly. This type settled along the northwest coast, in the central and eastern mound region, the Antilles, Mexico (including Yucatan), in the Gulf States, over much of Central America, reaching finally the coast of Peru and other parts of northern South America.

Still later, and when America was already well peopled, there came, according to all indications, the Eskimo and the Athapascan Indians. The former, finding resistance in the south which he could not overcome, remained in and spread over the far-north land, developing various environmental physical modifications that have removed him, on the whole, farther from the Indians than is the case with any other branch of the yellow-brown people. The Athapascans, a virile brachycephalic type, on the one side closely allied

physically to the prevailing Mongolian type of northeastern Asia and on the other to the earlier American brachycephals,⁷ may have reached the continent before the Eskimo. However this may be, their progress southward was evidently also blocked, compelling the body of the enlarging tribe to remain in Alaska and northwestern Canada; but along the western coast some contingents succeeded in penetrating as far as California, where they left the Hupa, and to Arizona, New Mexico, Texas, and parts of northern Mexico, where we know them as the Apache.

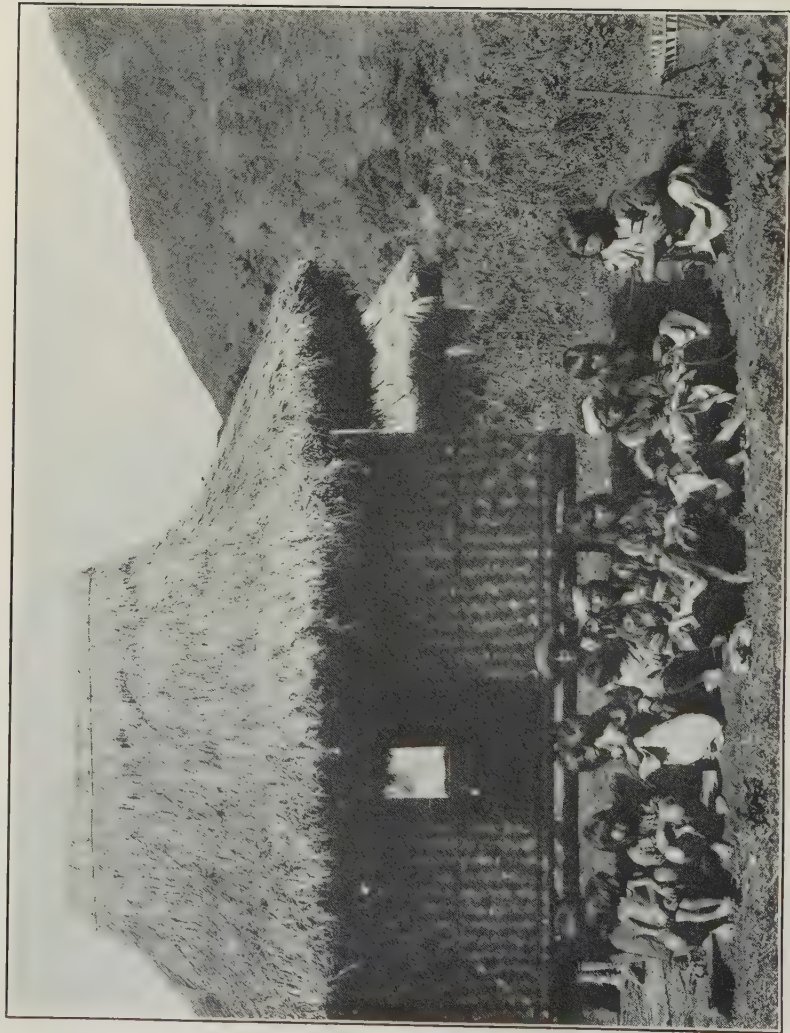
This, in brief, seems to be the story of the genesis of the American Indians as derived from the present and generally acceptable anthropological evidence. There are still many obscure spots which future knowledge may illuminate. The subject calls for continued research, especially in the American Northwest and in northeastern Asia. But the main facts appear now to be well established.

The peopling of America must have been one of the greatest romances of man's history—even though the beings coming over were no giants or dwarfs, as sometimes imagined, nor any very ancient form of man, but just ordinary "Indians."

⁷ See "Catalogue of Human Crania in the U. S. National Museum Collection," Proc. U. S. Nat. Mus., 1924, LXIII, art. 12.



IGORROTE GIRL CARRYING CHILD



IGOROTES, PHILIPPINE ISLANDS



A TINGUIAN MAN, PHILIPPINE ISLANDS



NATIVES OF PAGI ISLANDS, NEAR BORNEO

(Photographs by Dr. W. L. Abbott)



A BOY FROM PAGI-PAGI ISLANDS, MALAYSIA

(Photographs by Dr. W. L. Abbott)

THE ANTHROPOLOGICAL WORK OF PRINCE ALBERT I OF MONACO, AND THE RECENT PROGRESS OF HUMAN PALEONTOLOGY IN FRANCE¹

(The Huxley Memorial Lecture for 1922)

By MARCELLIN BOULE

Professor in the Muséum national d'Histoire naturelle, Director of the Institut de Paléontologie humaine

* * * * *

I have hesitated long over the choice of a subject to discuss before you. I am not an anthropologist in the strict sense of the term. My scientific equipment is rather in the domain of geology and of paleontology. It is through these two sciences that I have been led to take up anthropology. Since man is known in the fossil state, his earliest history will be revealed necessarily and directly through geology and paleontology, and will be revealed only through them.

It is your illustrious predecessors, Lyell, Prestwich, Falconer, Huxley, John Evans, who, following in the train of, and so to speak, coming to the aid of our great precursors, Tournal, Boucher de Perthes, Noulet, Lartet, have placed the problem of fossil man in its true perspective; it is their work which has thrown the first light on the great problems of geology and quaternary paleontology. The geological observations of Lyell and of Prestwich, the paleontological discussions of Falconer and of Mr. Boyd Dawkins, the anatomical and philosophical observations of Huxley, and the archeological speculations of Lubbock and of John Evans have lost nothing of their value, although the younger generations are showing too great a tendency to forget them.

I should have liked to discuss the underlying reasons for the development of that fine group of British scientific men devoted to solving the great problem of our origin by the most varied methods, a group whose ranks are still far from complete, as is shown by the discoveries and investigations of every kind accomplished by you and in your country in recent years. I feel that these are correlated, at least in large part, with the geographical and geological environment. All of the geological systems that are elsewhere isolated are found

¹ Translated, by permission, from the Journal of the Royal Anthropological Institute of Great Britain and Ireland, Vol. LII, July to December, 1922.

within your territory. From the geological point of view, your Pliocene and Pleistocene formations are most varied; you have marine formations, glacial formations, alluvial formations, accretional deposits, bone caverns, peat bogs, etc. The study of the stratigraphic relations of these diverse formations led you early to particularly interesting and accurate results. It is certain, for instance, that the early observations of Lyell and of Prestwich still remain of prime importance.

From the paleontological point of view, you have, in your Pliocene outcrops of Norfolk, in the Pleistocene alluvial formations of your great valleys, in the refuse deposits of your caves, in your peat bogs, etc., an almost uninterrupted succession of fossil faunas whose study, connected with a stratigraphic study, is of a nature singularly adapted to the solution of chronological problems.

From the archeological point of view, your situation is somewhat peculiar, but it is found that at different epochs, the connection of your country with the continent has provided access to it for the oldest populations of western Europe, so that you do not lack evidence bearing on the ethnography of these early men, and you are able also, perhaps better than elsewhere, to establish the most instructive relations between all the data of geology, of paleontology, and of prehistoric archeology.

Such a subject would therefore have much attraction for me; but to treat it suitably before you, I should have had to devote to its preparation much more time than my professional duties will permit. I was still hesitating when there occurred a tragic event, the death of Prince Albert I of Monaco, whose name will live, as you know, as one of the greatest benefactors of science, and of whom I had the honor of being one of the closest collaborators. Everyone knows to-day the services which the prince has rendered to oceanography. Much less well known, though not less great, are the services which he has rendered to human paleontology. It seemed to me that I should be able to interest you in speaking to you of an illustrious and mourned benefactor of anthropology, and that I would fulfill a duty in paying to his memory, before a select audience, the homage which is due him. The anthropological work accomplished by the Prince or by his collaborators is such that in describing it I shall be able at the same time to indicate to you the greater part of the progress recently made in France in the field of human paleontology.

What I especially desire to explain to you is that the part played by the Prince of Monaco was not that of a mere amateur nor of a mere patron. He brought to the study of the great problem of the origin of the human race the enthusiasm, and especially the spirit of cooperation which he showed in his oceanographic investigations, in attack-

ing the more general problem of the origin of life. In each case, he has given lavishly not only of his money but of himself.

All tourists who have visited the Côte d'Azur, toward the French-Italian frontier, know the Baoussé-Roussé, or Red Rocks, whose escarpments, terminating the chain of the Alps on this coast, drop perpendicularly to the sea, not far from Menton, but on Italian territory, below the ancient village of Grimaldi, once the property of the Princes of Monaco.

These superb rocks, with their warm coloring perpetually flooded with bright sunlight, are honeycombed with caves which open broadly on the azure sea in an enchanting region. These caves have long been well known as a result of the discoveries which have been made there at various times. It seems that it was a Prince of Monaco, Florestan I, grandfather of Albert I, who first realized their scientific interest. At some time prior to 1848 he sent to Paris a box of miscellaneous débris collected in these caves. I do not know what was done with these bones and fashioned flints in Paris, but from the fact that they were sent 10 years before the triumph of Boucher de Perthes, the inference is that they were not appreciated at their true value by the men of science to whom they were probably shown.

The caverns of Menton were not long in becoming known and in receiving visits from various naturalists and archeologists. Some excavating, though only superficial work, had already been done there, when in 1870 a French physician, Emile Rivièrè, whose health forced him to live on the Côte d'Azur, undertook to explore the "caverns of Menton." His investigations were shortly to achieve success. In 1872 he found a human skeleton in the cave called Cavillon, under a covering of stalagmite. This is the famous "Menton man," now on exhibition in the hall of anthropology of the Paris Museum. The following year, in a neighboring cavern, he uncovered the remnants of three other skeletons. In 1874 and 1875 he took two children's skeletons from another cave, since called for this reason "Grotte des Enfants"—the Children's Cave.

These discoveries were widely noticed. Certain features about them recalled those of the formations at Cro Magnon in the Department of the Dordogne, explored some years before by Louis Lartet. They attracted quite as much attention. For Rivièrè as for Louis Lartet it was a question of burials of the Paleolithic age; that is, the Pleistocene. But such great antiquity was doubted by the majority of anthropologists who could not bring themselves to project so far into the past the type of *Homo sapiens*. The most formidable of these adversaries was Gabriel de Mortillet, who rendered great service to prehistoric archeology, but who often obstructed the progress of this science by his preconceived ideas and his antireligious beliefs.

It must be said that Rivière, whose recent death we mourn, had neither the scientific training nor the necessary genius to prove his case, although it was a worthy one. He was reproached with not having conducted his excavations methodically or with sufficient care, with not having established the stratigraphy of his positions, with having confused the various levels, and with having relied upon the statements of his workmen. The great work which he published in 1887 on *The Antiquity of Man in the Maritime Alps*, poorly planned and inaccurate on important points, was an insufficient reply to these criticisms, and the opinion of G. de Mortillet on the Neolithic age of all the skeletons was generally accepted, accompanied in certain minds, however, by distressing reservations.

At this point there came upon the scene the Prince of Monaco, whose keen scientific spirit had already long been exercised in the domain of anthropology as well as in many other directions. From his youth, in fact, he had anticipated his later work and had prepared for it in the laboratories of Paris, discussing paleontology with Albert Gaudry, studying prehistoric archeology with G. de Mortillet, and working with Manouvrier on human skeletons. In 1882 and 1883 he was engaged in exploring one of the finest caves of the Baoussé-Roussé, the Barma Grande, working himself with his own hands and scrupulously keeping in a notebook the record of his excavations. "The undertaking of the Prince of Monaco," M. de Villeneuve tells us, "has this special characteristic: It contemplates less the assembling of a collection of prehistoric objects than the acquisition on the spot of facts with which in his opinion the laboratory study of the material may be correlated in such a way as to make all the results of an excavation available for science."

When he was obliged to be away, he charged his archivist, M. Saige, with continuing the investigations and gave him exact instructions: "No one shall work on the excavations except in your presence * * *. It is essential to establish as exactly as possible the levels in which the various fragments have been found in relation to the absolute surface of the ground, and especially to establish the relations of these different levels to each other. It is necessary also to note the thickness and the situation of the sterile strata—that is, those which produce nothing—for they indicate a period during which the cave was abandoned * * *. A diary must also be very carefully kept, so that when the cave has been completely excavated its history may be written." And he indicated the manner of working by digging, first, a reconnaissance trench, by following this with horizontal trenches, by sifting the earth, etc. He did not hesitate to go into the most minute technical

detail.² These are not, we see, the methods of a mere amateur but those of a true man of science.

As a result of the various kinds of difficulties which he encountered the Prince wrote from Paris on June 15, 1883, "I see, from the complications which our excavations are continually encountering, that we must abandon the caves for the time being." But this proved only true in part. More and more desirous of achieving the solution of the important problems of prehistoric anthropology which presented themselves at the Baoussé-Roussé, the Prince decided in 1895 to take up again the work of systematic exploration, at first in a cave still nearly intact—the "Grotte du Prince"—then in some of the neighboring caves which already had been superficially excavated but whose deposits of refuse were still partly in place.

These new excavations lasted nearly 10 years. They were conducted by M. le Chanoine de Villeneuve and his aid, M. Lorenzi, methodically, skillfully, and with devotion, as I am able to testify through my frequent and long stays in Monaco. They furnished valuable scientific results, which were presented in a large work published sumptuously under the auspices of the prince.³ I shall call your attention for a moment to the most important of these results.

The "Grotte du Prince" is the largest of the group. The exploration work took out more than 4,000 cubic meters of the material, which filled it and permitted the study of two kinds of deposits:

1. The lowest—that is, the oldest—represents an ancient coast line, with Mediterranean shells and without northern species; Senegalese forms, such as *Strombus bubonius*, indicate warmer water than at present.

2. Over this marine formation are superimposed, more than 15 meters in thickness, formations of subaerial origin in which are found fireplaces, or heaps of ashes, especially rich in bones of animals and corresponding to the successive periods of human occupation. Two groups of fireplaces can be distinguished. A lower group is characterized by mammals of the oldest period of Quaternary time, and denoting a warm climate, such as the hippopotamus. The higher group contains the bones of "cold" species, such as the reindeer.⁴ The superposition of these two faunas—one warm, the other cold—had not before been established in a country so far south.

² See L. de Villeneuve, "Les Grottes de Grimaldi, Historique et Description," p. 31.

³ L. de Villeneuve, M. Boule, R. Verneau, E. Cartailhac, "Les Grottes de Grimaldi," 2 vols., quarto. Monaco, 1906-1919.

⁴ The reindeer is not the only "cold" species which I have observed for the first time in that region. Among the bones resulting from excavations recently carried on by M. de Villeneuve in a cave of Monaco, I had the pleasure of recognizing a skull of *Isatis* (blue fox).

The stratigraphic and paleontological study of the "Grotte du Prince" has shown us that this succession should be admitted for the Côte d'Azur as well as for the Pyrenees, the banks of the Seine, or those of the Thames.

But there was an outcome even more unexpected. It is not the culture known as Chellean which was found in the lower levels with the warm fauna, the fauna of the lower Pleistocene, but rather the Mousterian culture, commonly associated in Europe with the mammoth fauna. This fact caused surprise, I might almost say consternation, among the prehistoric archeologists, too prone to believe in the stability and the chronological infallibility of the various types of Paleolithic implements. They discussed it freely and interpreted it in various ways. Of the two conflicting methods—the geological and the archeological—I firmly believe that here the latter should give way to the former. The facts of a geological and paleontological nature have a more general signification and bearing than the ethnographic facts because they do not depend, as do the latter, on human action. I am able, moreover, to announce to you the very recent discovery by M. de Villeneuve, of a rude Chellean industry in the cave of "l'Observatoire," located in Monaco itself, and in a stratigraphic level situated rather above than below the level of the warm fauna and the Mousterian industry of the "Grotte du Prince." It is therefore not to be doubted that since the lower Pleistocene there have been different archeological facies in the several regions inhabited by men who might also have differed among themselves.

The "Grotte du Prince" has taught us many other things. The exceptional fact of the existence, at the same place and in contact with each other, of a marine fauna and a fauna of Pleistocene mammals, has put a new light on the chronology of the changes during Quaternary time in the level of the ocean and in the configuration of the Mediterranean shores. I have attempted to establish the relation of these variations to glacial phenomena and to the phenomena of erosion and filling in of valleys, and in the light of all these facts, to explain the exchange of faunas between Africa and Europe. Moreover, the fine state of preservation of the innumerable paleontological specimens collected in this cavern has enabled me to bring new facts to bear on the history and the geographical distribution of the Pleistocene mammals.

But the "Grotte du Prince" did not yield the slightest trace of human remains, and this was most unfortunate, for we had counted on the integrity of the deposits of this fine locality to determine once for all the age of the various burials found in the neighboring caves, concerning which discussion was still going on.

The Prince decided then to move his workshop elsewhere. The "Grotte des Enfants" had been only partly excavated. There still remained nearly 8 meters in thickness of untouched deposits. Here the investigations achieved the greatest success from an anthropological point of view: Four human skeletons were discovered at three different levels. The stratigraphic and paleontological observations made it possible to solve definitely the problem of the age of the formerly and recently discovered human skeletons at the Baoussé-Roussé.

The chief conclusion from these observations is that all of the skeletons are indeed Pleistocene. Those from the upper layers go back at most to the reindeer period. My learned colleague and friend, M. Verneau, who had already published interesting accounts of the skeletons of the Barma Grande, was invited by the Prince to make an anthropological study of them. He had no difficulty in showing that both belonged clearly to the Cro-Magnon race. It was the task of my dear friend Cartailhac, whom our science has mourned for a long time, to show in the archeological memoir, which he willingly undertook to prepare, that all of these burials, those of the Dordogne as well as those of the Côte d'Azur, were associated with the same accessories, pierced shells, objects of ornamentation, bone colored red, etc., and all bore witness to the same culture.

The two skeletons from the lower level are of an earlier epoch, of an age difficult to determine exactly, but which I have every reason to believe Mousterian, or closely allied to Mousterian. They also constituted a burial, and you all know that after having made a careful study of them M. Verneau concluded that they belonged to a special race, presenting numerous negroid characters, which he called the "Grimaldi race." The fact is of prime importance for several reasons. First, because we are here in the presence of a human type of an age very near that of the Neanderthal, if not of the same age, and the coexistence in western Europe in the same geological epoch of two such different human forms gives us much to think about; also because the resemblances of this new type, showing many traits in common with certain African races of *Homo sapiens*, lead us to believe that the "statuettes of Menton," with equally negroid and steatopygous characters, are rude effigies of this type.

The authenticity of these statuettes was discussed for a long time, especially because the exact circumstances of their discovery remained quite obscure, Rivièrè and G. de Mortillet considering them as the work of a clever forger who attempted to imitate the ivory figurines discovered by Piette à Brassempony in the Pyrenees.

Another objective of the excavations organized by the Prince was to clear up this mystery. In this respect also the results were noteworthy. Although no new statuettes were discovered, there was found in an Aurignacian fireplace of the "Grotte du Prince," a fragment of soft rock, or steatite, identical with the material of the first statuettes, which showed the beginnings of sculpture. If there was still needed additional proof of the authenticity and of the antiquity of these objects of primitive art, it was found in the uniformity of physiognomy and in the general similarity shown by all the works of the same class made in different countries quite distant from each other. Very recently, this summer in fact, M. and Mme. de Saint-Perier discovered in a cave in the Pyrenees, also in an Aurignacian stratum, a fine female statuette in ivory, one of the most beautiful objects which has been found so far in a Paleolithic deposit. The style of this statuette is very close to that of the Menton figurines. You will very shortly see photographic reproductions and a description of it in "L'Anthropologie."

These are the chief results of the work carried on under the direction and at the expense of the Prince of Monaco in the caves of Grimaldi. The precious relics resulting from these excavations and brought to light after so many thousands of years constitute the most venerable archives of humanity. They must be preserved as we preserve the archives of written history, and with this end in view the Prince organized the Anthropological Museum of Monaco, the direction of which he entrusted to his learned and devoted collaborator, M. de Villeneuve. Here are exhibited methodically, in galleries lighted by great bays opening on the blue sea, an innumerable series of objects carefully arranged and labeled. Large specimens give an idea of the character and the composition of certain fossil-bearing strata. Vertical glass cases are filled with fine paleontological specimens. The human skeletons occupy the center of the main hall on the first floor. They are surrounded by archeological objects classified by levels. On the walls, plans and sections of the caverns of Baoussé-Roussé enable visitors to visualize the nature and the stratigraphy of the positions. The other halls contain, among other collections, the results of similar excavations carried on in various caves located in territory belonging to the principality, notably in the Neolithic caves of Bas-Moulins and the Spélugues. All this material forms a whole which daily attracts many visitors and which keenly interested the members of the thirteenth session of the International Congress of Anthropology and Prehistoric Archeology held in Monaco in 1906.

The Prince also rendered still another great service to our studies when he took this Congress, whose fate appeared at that time very doubtful, under his protection. And those among you who were

present at the session at Monaco still recall the success of this gathering, enriched with all the delights of a truly princely hospitality. May I be permitted to here express regret that after the terribly sterile period of the Great War anthropologists have not recognized that instead of seeking to create a new more or less international organization they should devote themselves to reviving an institution whose brilliant past should vouch for the future?

The Prince, pleased with the results which he has thus obtained, looked only for a new opportunity to render further services to the study of human paleontology. Such an opportunity was not long in presenting itself. On all sides discoveries relative to Quaternary art were multiplying. Cartailhac returned from Altamira with portfolios full of photographs and crayon sketches cleverly drawn by M. Breuil. In his enthusiasm he had made magnificent chromolithographic plates for the work which he intended to publish with his collaborator. But he soon perceived that the undertaking was too great and beyond his moderate financial means. With the help of that learned and lamented archivist of the Palace of Monaco, Gustave Saige, I had no difficulty in interesting the prince in the incomplete work. He generously took over all the expense of the publication of this magnificent volume entitled "Altamira," to-day in every large library in the world, which is only the beginning of the list of a series of magnificent volumes devoted to the description of the mural paintings and engravings of the Paleolithic caverns.

M. Breuil was particularly adept in this new form of investigation. The prince gave him every facility for pursuing his work not only in France but also in Spain; and it is to this interest that the broad scope of prehistoric studies in the Iberian peninsula, a development of which we have been for some years the admiring witnesses, is due.

This period of about 10 years immediately preceding the terrible phenomenon of human retrogression provoked by Germany in 1914, was in France truly a great period for human paleontology and prehistory. Investigators were numerous; they made valuable observations and sometimes important discoveries in all parts of France. In the Pyrenees, already well known through the finds and the investigations of Piette, it was shown by Cartailhac, Breuil, and Begouen that many of the caves were real museums of Quaternary art whose masterpieces they hastened to make known to us through preliminary publications. In the Dordogne, Rivière, Capitan, Peyrony, Bouyssonie (I mention only the most able or the most fortunate workers) also made great discoveries. Doctor Lalanne revealed to us the superb frieze of sculptured horses and the bas-reliefs of human figures of Laussel. And, at the same time, MM. les Abbés Bardon and Bouyssonie exhumed the man of Chapelle-

aux-Saints, MM. Capitan and Peyrony discovered in the deposits of la Ferrassie a whole series of skeletons of the same period and no less well preserved; while not far from there, at La Quina, Dr. H. Martin made similar finds of equal interest. Thanks to all these important discoveries, it has been possible to study the Mousterian man of our country, the *Homo neanderthalensis*, in as complete a manner as possible, in all parts of his bony framework, which is to-day better known to us than that of many present-day savages. The multiplicity of discoveries has enabled us to demonstrate the very interesting homogeneity of this archaic type. This constitutes a great step forward in the domain of human paleontology, and the mind of the Prince of Monaco was keenly alive to it.

The first in chronological order of these discoveries, that of the man of La Chapelle-aux-Saints, caused a great stir. After its presentation in purely scientific publications, the press made it known to the public, which evinced a keen interest in it. At this time innumerable visitors passed through my laboratory in the museum to see the skull which had already become famous, and these visitors came from every social and intellectual class of the capital. The Prince of Monaco himself joined this pilgrimage. He came to see me one summer afternoon. Greatly impressed by the sight of this venerable osteological specimen, he stayed for a long time contemplating it, examining it from all sides, studying the peculiar details of its morphology. Then evening came on; the setting sun flamed beyond the dome of the Panthéon and the more slender silhouettes of the other monuments of Mount Sainte-Geneviève. There, in this beautiful setting, the Prince made me a part of a new project which he had been considering for a long time and which he now decided to put into execution. He requested me to prepare for him a plan of organization for an institute of human paleontology.

His mind had been keenly struck by the contrast presented by the immense interest and the philosophical importance of our studies and the paucity of means of action heretofore put at the service of human paleontology, truly a French science, though almost ignored by the powers that be in the official, academic, and university circles of our country. And in his great generosity he wished to be the Prince Charming to this new Cinderella. He clearly defined his purpose in the first phrase of the letter which he wrote on November 23, 1910, to the Minister of Public Instruction in announcing his intentions:

"In the course of my busy life," he said, "I have often regretted that in the intellectual movement of our time more prominence has not been given to the study of the mystery which envelops the

origin of humanity. As my mind has been more and more enlightened through scientific study, I have wished more and more ardently to see established on a methodical basis the investigations necessary to bring to light the fugitive traces which our ancestors have left in the bowels of the earth during an incalculable succession of centuries. And I have thought that the philosophy and the morale of human societies would be less uncertain in the presence of the history of generations written with their own dust."

Having thus resolved to create "a powerful center for studies based on methodical excavations," the Prince of Monaco presented it with the building necessary for its establishment and with an endowment of 1,600,000 francs. On December 15, 1910, the Institute of Human Paleontology was recognized as a public utility by the French Government.

According to its plan of organization, the new establishment, placed under my direction, has for its purpose the progress of science on all questions relating to the origin and history of fossil man.

The principal means of action are: (1) Laboratories where the results of excavations carried on by the personnel of the institute or by other workers under its direction are studied; (2) publications to make known the results of the excavations and of scientific investigations; and (3) courses and lectures on human paleontology and prehistory.

Without waiting for the construction of the building, which would require some time, Professors Breuil and Obermaier undertook in France, in Spain, and in central Europe extensive explorations and excavations, while some independent workers were through grants assisted in their investigations.

The new edifice constructed by the architect Pontremoli was soon finished. To-day it adorns, with its beautiful façades, that part of the Boulevard Saint-Marcel recently occupied by the horse market. Its façades are the work of the clever chisel of M. Constant Roux, for which the theme was furnished by our founder himself. The Prince of Monaco desired, in fact, that his new institute should have an attractive exterior in a relevant as well as artistic style, revealing at first glance, through the choice of the decorative motifs, all the interest of the studies which are carried on there.

Large basements contain rooms for the unpacking and provisional classification of the results of excavations and workshops for preparation of material and for modeling. On the ground floor there are a large hall for lectures and exhibits, general administrative offices and chemical laboratories, and the workrooms of the professors.

The institute is not a museum, and its purpose is not to accumulate collections. But it should have for instruction and for study as complete a series as possible of objects for comparison in the various fields of prehistoric ethnography, anthropology, comparative anatomy, and the paleontology of the late geological epochs. These series, of the greatest importance to-day, are arranged and classified in three rooms, called rooms for comparative studies, which encircle the first floor, and a large library which is complementary to these, the objects to be studied near the books. The library, which has just been enriched by the fine collection of Emile Cartailhac, is also arranged as a workroom, and several offices on this same floor are reserved for distinguished scientists who wish to visit the institute.

The material from the excavations, unpacked, sorted, cleaned, and prepared in the basement rooms, photographed on the ground floor, and studied on the second floor, may then form the subject of published memoirs. The third story contains besides a drafting room, compartments where the publications are stored. These serve to enrich the library of the institute through exchanges. Some copies are sold commercially through MM. Masson et Cie., publishers.⁵

The institute was to have been opened at the end of 1914. The war played havoc with it as with all other scientific establishments. For six years it was forced to live a stunted life. On December 23, 1920, it was officially opened in the presence of M. Millerand, President of the French Republic, and many guests, including members of the Government, and of the diplomatic corps, representatives of great scientific establishments, learned societies, the press, etc.

One year later, on February 18, 1922, the Prince had the pleasure of presiding at the first public lecture, and of verifying the truly popular success of the undertaking he had recently inaugurated. In spite of a state of health which already caused keen anxiety among his friends, he delivered an address in which, as always, originality and richness of form clothed strong and noble thoughts, and of which each phrase bore witness to his respect for and love of science. "You are here," he said, "in a new temple which I have created in order that anthropology, supported by sound laws, can soar one day over the mysteries which surround us. I hope that it may bring to civilization the cooperation of the great forces contained in its bosom, which will purify our customs, our ideas,

⁵ The principal publications are: "Les Grottes de Grimaldi," by MM. de Villeneuve, M. Boule, E. Cartailhac, R. Verneau, 2 vols., quarto, with 64 plates in heliogravure; the series, comprising 5 vols. in quarto, on the "Peintures et gravures murales des cavernes paléolithiques," with a total of 217 plates in black and in colors; "Les anciens Patagons," by Dr. R. Verneau, 1 vol. in quarto, with 15 plates; the 13th session of the "Congrès international d'Anthropologie et d'Archéologie préhistoriques," Monaco, 1906, 2 vols., octavo; and a little series of "Rapports annuels," by the director and the professors.

our social relations, when humanity knows whence it came and understands where it is going." The audience, which could not all be accommodated in the lecture hall, thanked him by long applause.

This was his last visit to the establishment of which he was justly proud and for which he showed the affection of a father for his last-born. Some weeks later, on his sick bed, he talked with me of the great future he foresaw for our science. And in an affectionate tone which I shall never forget, he wished to thank once more his collaborators for the intellectual pleasures which they had provided him, the pleasures to which this sovereign prince attached the greatest value. Some weeks later, on June 26 last, he succumbed. His will, drawn in terms of rare nobility, constitutes a final glowing testimonial of his devotion to the interests of science, the chief aim of a life wholly devoted to labor and to the progress of humanity.

You have here, gentlemen and dear colleagues, an existence and a work which overstep, through their greatness and importance, the limits of geographical territory where they were begun. The eminent services rendered to science by Prince Albert I, of Monaco, were not exclusively in favor of that France of which he was always the faithful and devoted friend. The results accomplished, thanks to his influence and to his liberality, are to-day a part of the universal patrimony. And his activity, from which my country was the first to benefit, was also beneficial to other countries, where it acted as a sort of catalytic force, inciting great activity in the field of our studies and inducing emulation everywhere. It is, therefore, not alone the progress in France in the course of these last 20 years in the domain of human paleontology which resulted in great part from the anthropological work of Prince Albert; the progress made nearly everywhere also depended on it in a more or less direct way.

It was through the unlimited realization of progress of this kind that this "prince of science and art," this "useful prince," foresaw for humanity better days, as shown by this phrase written by him: "I have cultivated science because it diffuses knowledge, and knowledge engenders justice."

THE RUINED CITIES OF PALESTINE, EAST AND WEST OF THE JORDAN¹

By ARTHUR W. SUTTON, Esq., J. P., F. L. S.

[With 8 plates]

The view of Beirut as we enter the harbor is most beautiful. The foreshore, covered with red-tiled houses, is backed by groves of mulberry and pomegranate trees; and behind these are the sloping hillsides terraced with the cultivation of vines and olives, with the mountains of Lebanon in the distance covered with snow.

After crossing for some miles very soft plains, once vineyards and olive yards, but now a sandy desert with a few pines, planted a hundred years ago by the governor of Beirut to consolidate the soil, we come to the River Damur and then to the orange groves round Sidon, second only to those at Jaffa. Sidon is not only the most ancient city of Phœnicia, but one of the oldest of the known cities of the world, and is said by Josephus to have been built by Sidon, the eldest son of Canaan, and is mentioned with high praise by Homer in the *Iliad*, where he says that as early as the Trojan war the Sidonian mariners, having provoked the enmity of the Trojans, were by them despoiled of the gorgeous robes manufactured by Sidon's daughters, these being considered so valuable and precious as to propitiate the goddess of war in their favor. Sidon was renowned for its skill in arts, science, and literature, maritime commerce and architecture; and according to Strabo the Sidonians were celebrated for astronomy, geometry, navigation, and philosophy.

Sidon was captured by Shalmaneser in 720 B. C., and it was again taken in 350 B. C. by Artaxerxes Ochus. It fell to Alexander the Great without a struggle, and afterwards came into possession successively of the Seleucidæ and the Ptolemies. During the time of the Crusaders Sidon was four times taken, plundered, and dismantled. Excavations have revealed several rock-hewn tombs, with elaborately carved sarcophagi. The most celebrated is the sarcophagus of Alexander, which before the war was in the mosque at Constantinople. He was certainly never buried in it. A sarcophagus was opened the other day at Sidon, full of fluid and containing a beautiful body in perfect preservation, but immediately it was lifted from the fluid it lost all shape.

¹ Read before the Victoria Institute. Reprinted, by permission, from the Journal of the Transactions of the Victoria Institute, Vol. LII.

At Zarephath we saw the churning of butter in a leather bag full of milk, which is swayed backwards and forwards until it is formed.

This is the site of Sarepta, where Elijah raised the widow's son to life (I Kings, xvii, 8-24); and near here, on the coasts of Tyre and Sidon, our Lord healed the daughter of the Canaanitish woman.

We next approached Tyre, now called Sur, from which the name of Syria is derived—Syria really meaning the land of the Tyrians or Surians. The origin of Tyre is lost in the mist of centuries, and Isaiah says its "antiquity is of ancient days" (xxiii, 7). Herodotus states it was founded about 2,300 years before his time, i. e., 2750 B. C. William of Tyre declares it was called after the name of its founder, "Tyrus, who was the seventh son of Japhet, the son of Noah." Strabo spoke of it as the most considerable city of all Phœnicia. Sidon was certainly the more ancient city of the two, but Tyre by far the more celebrated and one of the greatest cities of antiquity. It was besieged by Nebuchadnezzar for 30 years. The siege of the city by Alexander the Great in 332 B. C. was the most remarkable and disastrous episode in the history of Tyre. The island city held out for seven months, but was finally captured by being united to the mainland by a mole formed of the stones, timber, and rubbish of old Tyre on the shore, which were conveyed into position by the Grecian army. Then the island was made a peninsula, in which form it exists at the present day. This siege was so remarkable a fulfilment of the prophesies of Ezekiel that the words of the Hebrew prophet read more like a history than a prediction. "Therefore thus saith the Lord God: Behold, I am against thee, O Tyre, and will cause many nations to come up against thee, as the sea causeth his waves to come up. And they shall destroy the walls of Tyre, and break down her towers: I will also scrape her dust from her and make her a bare rock. She shall be a place for the spreading of nets in the midst of the sea; for I have spoken it, saith the Lord God: and she shall become a spoil to the nations * * * and they shall make a spoil of thy riches, and make a prey of thy merchandise: and they shall break down thy walls and destroy thy pleasant houses: and they shall lay thy stones and thy timber and thy dust in the midst of the waters" (Ezekiel, xxvi, 3-5, 12).

In more modern times the city was taken by the Mohammedans, the lives and property of the inhabitants being spared on condition that there should be "no building of new churches, no ringing of bells, no riding on horseback, and no insults to the Moslem religion." Tyre was retaken by the Christians in 1124, but once more fell into Moslem hands at the final collapse of the Crusades in 1291. It was then almost entirely destroyed, and the place has never since recovered, though of late years there have been signs of a slight

revival of commerce, and the city is gradually becoming more populous. In the middle of the last century it had fallen so low that Hasselquist, a traveler, found but 10 inhabitants in the place.

The ruins which are now found in the peninsula are those of Crusaders' or Saracenic work. The city of the Crusaders lies several feet beneath the débris, and below that are the remains of the Mohammedan and early Christian Tyre. The ancient capital of the Phœnicians lies far, far down beneath the superincumbent ruins.

The ancient glory of Tyre has been described in Ezekiel with a graphic power of description and minute accuracy of detail which is scarcely equaled in the annals of literature. Strabo ascribes the prosperity of Tyre to two causes—"partly to navigation, in which the Phœnicians have at all times surpassed other nations, and partly to their purple, for the Tyrian purple is acknowledged to be the best; the fishing for this purpose is carried on not far off." The far-famed Tyrian dye was extracted from the glands of a peculiar species of shellfish (*Murex trunculus*). Pliny says that the reason why Tyre was so famous in ancient times was "for its offspring, the cities to which it gave birth."

Nearly the whole of ancient Tyre now lies buried fathoms deep beneath the surface of the sea, the only thing remaining visible now of the ancient city being an enormous mass of magnificent granite and marble columns and ruins, which lie in the northern harbor, submerged by the sea, but distinctly visible when the water is clear. Thus literally have Tyre's stones and dust been hid "in the midst of the waters." "What city is like Tyrus, like the destroyed in the midst of the sea?" (Ezekiel, xxvii, 32.)

Passing up the Wady Ashur, one of the most picturesque and interesting ravines in Syria, we find ourselves in the region of the wonderful Phœnician rock sculptures and tombs, and camp at Tibnin, whose fine large castle has been the chief feature of the landscape for some two hours before we arrive. The castle was founded by Hugh de St. Omer, Count of Tiberias, about 1104.

The second day's ride from Zarephath, where we had camped for our visit to Tyre, brings us to Safed, one of the four sacred cities of the Jews, occupying a conspicuous position on the summit and slopes of a lofty mountain, and supposed to be the place referred to when our Lord said "A city that is set on a hill can not be hid" (Matthew, v. 14). To-day it contains about 15,000 inhabitants—9,000 Jews, 6,000 Moslems, and a few Christians. Like many other towns of Palestine, it is filthy beyond description. It was almost entirely destroyed by the great earthquake of 1837, when great numbers of the inhabitants perished. Baldwin III fled here after his defeat in 1157, and Saladin captured it after the Battle of Hattin in 1187.

We now reach Tiberias. It has a population of about 6,000, of whom 4,000 are Jews, 300 Christians, and the rest Moslems, and is one of the four sacred cities of the Jews in Palestine. The earlier city of Tiberias was spoken of by Joshua (xix, 35) under the name of Rakkath. The Roman city was built by Herod Antipas, and dedicated by him to the Emperor Tiberias (A. D. 16). After the Battle of Hattin, 1187, Tiberias fell into the hands of Saladin.

The Hammam or hot baths (temperature 144° F.) are to the south of the city, and are visited by people from all parts of the country. They occupy the site of Hammath, spoken of by Joshua (xix, 35) and by Pliny. Our Lord never entered Tiberias, as, according to early tradition, it was built on an ancient cemetery.

We now proceed round the foot of the lake and up the gorge of the Yarmuk, from Tiberias to Deraa. Following the caravan road down the western side of the lake we come to an old ruined bridge over the Jordan, about a mile south of where it flows out of the Sea of Galilee, and ford the river on horseback; and after crossing the railway from Haifa to Deraa and Damascus at the station of Semakh, we follow the railway up the gorge of the River Yarmuk to the hot springs of Amatha. These springs are eight in number, some of them several miles up the valley, but the principal ones are close to a place called El Hamma. Their temperatures are 115°, 103°, 92°, and 83° F., respectively. The principal spring is in a basin about 40 feet in circumference and 5 feet deep. The water is so hot that the hand can not be kept in it for any length of time, and is considered by the Arabs to be a sovereign cure for many disorders. Herod is supposed to have come here to be cured, and the Baths of Amatha were considered by the Romans as second only to those of Baiae, and were much extolled by Eusebius and other ancient writers.

From the hot springs we climb up by a very steep pathway by the side of the gorge to Gadara, occupying a magnificent site on the western promontory of the plateau overlooking the Lake of Tiberias. Captured by Antiochus the Great, 218 B. C., it was, 20 years afterwards, taken from the Syrians by Alexander Jannæus after a siege of 10 months. The Jews retained possession of it for some time, but, the city having been destroyed during their civil wars, it was rebuilt by Pompey to gratify the desire of one of his freedmen, who was a Gadarene. It was surrendered to Vespasian in the Jewish war. It was one of the most important cities east of the Jordan and called by Josephus the capital of Peræa, and was subsequently the seat of the bishopric Palestina Secunda.

The ruins of the two open-air theaters still exist, one with a full view of the Lake of Galilee in the distance below. There are enormous quantities of tombs everywhere, by which the neighborhood



SIDON FROM THE SHORE



APPROACH TO TYRE



MARBLE SARCOPHAGUS LYING IN A FIELD AT BEIT-ER-RAS



ENTRANCE TO UNDERGROUND CITY OF DERÁÁ



THERMAE OF JERASH, LOOKING OUTWARDS FROM WITHIN



JERASH. "THE TRIBUNE"



GREAT TEMPLE OF THE SUN, JERASH



JERASH. FORUM IN FOREGROUND. STREET OF COLUMNS

is honeycombed, many of these having massive basalt doors which still swing on their hinges. More than 200 stone sarcophagi have been taken out of these tombs, and now lie scattered among the ruins of the city.

At Beit er-Ras we come on very extensive ruins—arches of great size, columns, Corinthian and Ionic capitals, chiefly composed of basalt; a vast subterranean ruin, with several fine arches underground. Inscriptions, chiefly Nabathean, are to be found among the ruins. This was a city of great importance in the Roman Empire, and has been identified with Capitolias, one of the cities of the Decapolis.

We now reach Deraa or Dera'a (old Edrei), which to-day is a junction where passengers dine on the railway journey to Damascus; it is a remarkable place, for at least four cities exist here one above another. The present Arab buildings are on the top of a Græco-Roman city, and this again stands on the remains of one still older, in which beveled stones are used. Beneath this again is a troglodyte city entirely excavated in the rock on which the upper cities stand, the subterranean residence of King Og. The following passages of Scripture refer to Edrei:

“Og, the King of Bashan, went out against them, he and all his people, to battle at Edrei” (Numbers xxi, 33). “Moses * * * after he had smitten * * * Og the King of Bashan which dwelt in Ashtaroth at Edrei” (Deuteronomy, i, 4). “Salecah and Edrei, cities of the Kingdom of Og” (Deuteronomy, iii, 10).

The most prominent of the ruins, covering a circuit of 2 miles, are those of a large reservoir of Roman times, fed by a great aqueduct. There is a building, 44 by 31 yards, with a double colonnade, evidently a Christian cathedral, but now a mosque. The most notable remains, however, are the caves beneath the citadel. They form a subterranean city, a labyrinth of streets with shops and houses, and a market place. This probably dates in its present elaborate form from Greek times, but such refuges must always have been the feature of a land so swept by Arab Tribes. The Crusaders who besieged it called it Adratum (*Encyclopædia Biblica*).

Merril writes: “When King Baldwin III (1144–1162) and his Crusaders made their wild chase to Bozrah, they went by way of Dra'a. The weather was hot, and the army was suffering terribly for want of water, but as often as they let down their buckets by means of ropes into the cisterns, men concealed on the inside of the cisterns would cut the ropes and thus defeat their efforts.” Probably the underground city has connection with all the important cisterns of the place.

From Edrei we travel to Jerash, or Gerasa, which is a city of stupendous ruins, second only to Palmyra in size and importance,

and second only to Baalbec in beauty of architecture. In many respects it surpasses them both, and as a perfect specimen of an ancient Grecian city it has no equal. These ruins, says Doctor Tristran, "in number, in beauty of situation, and in isolation, were by far the most striking and interesting I had yet seen in Syria." The later name, Philadelphia, was given to the city by Ptolemy II (Philadelphus), King of Egypt, who rebuilt the city in the third century B. C. Greek immigration flowed into Syria after the conquest of Alexander the Great. The Greeks gradually extended beyond Jordan, sometimes occupying the old sites and sometimes building new cities, as at Jerash.

According to Pliny, Gerasa was one of the original 10 cities of the Decapolis. It is mentioned by Ptolemy, Strabo, Pliny, and other Greek and Roman writers, but no details are given of its history. We are informed that it was noted for its men of learning, and that it was the "Alexandria of Decapolis." It does not seem to correspond to any Old Testament site. The Crusaders made a campaign against it, in trying to form an eastern frontier for the Holy Land.

Exactly how or when the city was destroyed is not known. After going down in the Mohammedan invasion, it was probably left deserted for hundreds of years, because the state of the ruins after 700 years points clearly to the action of an earthquake and not the hand of man. An Arabian geographer, at the beginning of the thirteenth century, describes Gerasa as deserted. Hence we have here a Greek or Roman town standing as it was left 700, if not 1,200, years ago.

High above the Peribolos or Forum, on a rocky knoll, supported and surrounded by a massive substructure, stands the ruin of a great temple, whose superb situation commands the whole town and looks straight north along the colonnaded street. The walls of this temple are $7\frac{1}{2}$ feet thick.

Outside the city, says Doctor Green, there are the remains of a naumachia or theater, for the representation of naval spectacles, consisting of a vast stone reservoir 700 feet by 300 feet, surrounded by tiers of seats and supplied by conduits.

Not very far off is the site of the great and important city of Rabbath-Ammon, the ancient capital of the Ammonites, who, with the Moabites, are said to have been descended from Lot. These two nations drove out the gigantic aboriginal inhabitants east of the Dead Sea and the Jordan. Rabbath-Ammon is first mentioned in Deuteronomy III, 11, as the place where the "iron bedstead" of the giant King of Bashan was deposited; but it is celebrated chiefly for the siege against it by the Israelites under Joab, when Uriah the Hittite was slain—the blackest spot in David's history.

There are the ruins of a theater in good preservation, with 48 tiers of seats calculated to hold 6,000 people, and so admirably arranged that, as may be tested to this day, ordinary conversation on the stage could be distinctly heard on the topmost semicircle.

Joab first took "the city of the waters"—that is, evidently, the lower town, along the banks of the river. But the citadel still held out, therefore messengers were sent to David asking for a reinforcement and the presence of the King himself, in consequence of which David went in person and captured the citadel, with an immense quantity of spoil. In the third century B. C. the city was rebuilt by Ptolemy Philadelphus, King of Egypt, and called Philadelphia, under which name it is frequently mentioned by Greek and Roman writers. There are the remains of a large Christian church in the lower city.

The exterior walls of the citadel are constructed of large stones closely jointed, without cement, bearing in places the marks of high antiquity. The most interesting building on the citadel hill appears to be a specimen of the Sassanian architecture of Persia, probably dating from the same period as the Dome of the Rock at Jerusalem. The paneling and scrollwork on the walls is very beautiful and perfect, closely allied to Assyrian work. These buildings form a link between the Byzantine architecture and that of Persia.

We next reach what is evidently the site of Medaba, a city of the Moabites, taken by Joshua and given, with its plain, to the tribe of Reuben (Numbers, xxi, 30; Joshua, xiii, 9, 16). It was on the plain east of the city that Joab defeated the combined forces of Ammon and Syria, avenging the insult offered to the ambassadors of King David (I Chronicles, xix).

Madeba was recaptured by the Moabites at the Captivity and is therefore included in the prophetic curse pronounced upon Moab in Isaiah, xv, 2. It was an important fortress during the rule of the Maccabees and it became an episcopal city in the early centuries of our era. Here was discovered a large tessellated map of Palestine.

Not far from Madeba is Dibon, which is now nothing more than a shapeless mass of ruins, but obtained a new celebrity in 1868 by the discovery of the Moabite Stone, containing a long inscription in which is recorded some of the acts of that King Mesha who is mentioned in II Kings, iii. The inscription is in the old Phœnician character and appears to be of the age of Mesha. The stone was unfortunately broken by the Arabs, but most of the fragments are now in the Louvre.

Mount Nebo runs out westward from the plateau with a narrow ridge, at trend of which is the summit, Pisgah, and the ascent to this ridge is Sufa or Zophim. Here we stand on a site rendered memorable by two important events connected with the history of

the Israelitish occupation of Canaan. Hither Balak brought Balaam to curse the people (Numbers, xxii-xxiv), and hence Moses viewed the Promised Land (Deuteronomy xxxiv, 1). But toward the west, in the direction which Moses surveyed, there is a very wide and extensive view. The mountain ranges of Judea lie straight before us, with Jerusalem, Bethlehem, and the Frank Mountain clearly visible. The Russian Tower on the Mount of Olives and the summit of Neby Samwil are conspicuous objects in their midst. To the southwest is seen the ridge of Beni N'aim, near Hebron, whence Abraham beheld the smoke of the burning cities of the plain, whilst north of Olivet is seen the cone-shaped hill of Ophrah. The hills of Samaria are yet farther to the right, with Tell'Asur—the ancient Baal-Hazor—Ebal, Gerizim, and Bezek prominent amongst them. Gilboa, Tabor, and the heights beyond Beisan are visible on a clear day; but Carmel and Hermon are hidden from view, the former by the intervening heights of Jebel Hazkin, on which stands Bezek, and the latter by Neby Osh'a. The whole of the Jordan Valley, with the river itself meandering in serpentlike curves in its midst, lies outspread like a map at our feet, bathed in sunny verdure in early spring, at which time of the year Moses appears to have viewed it. From north to south “the land of Gilead toward Dan, Naphtali, Ephraim, and Manasseh—all the land of Judah, toward the utmost sea (the Mediterranean), the southern hills, and the plain of Jericho” (Deuteronomy, xxxiv, 1-3)—all these the aged “servant of God” could embrace within the compass of his vision without the aid of any miraculous powers.

Hebron, which we next reach after crossing the Jordan and passing south by Bethany and Jerusalem, is one of the oldest cities of the world. It was known at the time of its capture by the Israelites under Joshua as Kirjath-Arba, which means the “Fourfold City.” Probably, like Jerusalem at the present day, it was divided into four quarters, inhabited respectively by different races of people. The Septuagint describes it as the “metropolis of the Anakim.”

It is known as “City of Abraham, the friend of God,” to the Arabs, who have abbreviated the name to El Khalif—“The Friend” or “The Beloved.” It is one of the four sacred cities of the Moslems.

Haram: Cave of Machpelah. Travelers are not admitted within the precincts of this mosque, though a few royal European visitors have been privileged to enter this most cherished Moslem sanctuary by special Irade of the Sultan. This is one of the “Sacred Sites” of Palestine, about the genuineness of which there can be little or no doubt. It is almost certain that the mosque stands over the original Cave of Machpelah, which was the burial place of Abraham and Sarah, Isaac and Rebekah, Jacob and Leah. The mosque itself was

originally a Christian church founded by Justinian in the sixth century and completed by the Crusaders. It has, however, been considerably altered by the Moslems. There are six monuments, said to stand over the spots where the tombs of the six male and female patriarchs are located in the cave below. The Crusaders, impressed by the veneration accorded to the Cave of Machpelah by the Arabs, who claim to be the sons of Ishmael, the son of Abraham by Hagar, called the place the Castle of St. Abraham.

Hebron was at one time the capital of King David. He made it the base of his operations against Jerusalem, which in turn became his royal city. Absalom made it the headquarters of the unsuccessful rebellion against his father. Hebron lost importance after the Captivity, and in the time of the Romans it was hardly reckoned as being a Jewish town. The large square stone reservoir, now called the "Sultan's Reservoir," is the Pool of Hebron, where Rechab and Baanah, the murderers of Ishbosheth, were hanged by David (II Samuel, iv, 12). There is little else to see in Hebron, with the exception of the glassworks.

Beit-Jibrîn (House of Gabriel) was in the much contested borderland between the Hebrews and the Philistines. It was known to the Israelites as Mareshah and was fortified by Rehoboam, who "built cities for defense, Gath and Mareshah" (II Chronicles, xi, 8) :

This district was at some time inhabited by people who devoted an almost incalculable amount of time and trouble to the formation of great artificial caves. The result of this energy is concentrated as in a nucleus in the immediate neighborhood of Beit-Jibrîn. It is difficult to give an account of the principal excavations of this type without appearing to use the language of exaggeration. Except for their immense size, the Beit-Jibrin caves are of comparatively small interest. Prof. G. A. Smith (see his entrancing volume on the Historical Geography of the Holy Land) and others adopted the view that the caves as we see them are the work of the early Christian inhabitants of Palestine, because of the destruction of Jewish tombs in the course of cutting out the caves, the various Kufic and Christian inscriptions on the walls, etc. It was the seat of a Christian bishop as early as the fourth century. The Crusaders, who were powerfully established at Beit-Jibrîn, which they called Gibelin, beautified one cave by a handsome Romanesque doorway.

To sum up the subject of the "Riddle of the Caves" in the district round Beit-Jibrîn, there is an innumerable number of artificial caves. The date of a few of these is later than the Jewish period; a few others are demonstrably earlier than the end of the Jewish

monarchy, and there is Scriptural evidence that similar caves existed at an earlier date still (Judges, vi. 2): "Because of Midian the Children of Israel *made them* the dens which are in the mountains and the caves and the strongholds." This shows that such artificial caves were made in the times of the Judges for refuges. Certain chambers were prepared as cisterns, store chambers, etc. There is no means of dating such chambers. Other chambers were used for religious rites, filters, prisons, quarries, traps for wild beasts, etc.

We next reach Gezer. The site of this famous ancient city had been forgotten in modern times until about 1870, when Professor Clermont-Ganneau commenced his research. Biblical records of the city commence with the time of Joshua. Its king, Horam, helped Lachish against Joshua's attack, and he and his army were utterly annihilated (Joshua x, 33). Gezer was allotted to Ephraim who, however, failed to drive the Canaanites out (Judges, i, 29). Other historical sources carry us back to the time of Thothmes III, who captured it about 1500 B. C., though the excavations prove the history of Gezer to go back a further 1,500 years, of which there is no written history.

Canaanites, Israelites, Arabs, all have successively inhabited the mound through the centuries. We read in I Chronicles, xx, ~~34~~, of Philistine giants whom David's men slew at Gezer. The Canaanites lingered on in Gezer until the reign of Solomon. When Solomon celebrated his marriage with the daughter of the King of Egypt, the Pharaoh "went up and took Gezer and burnt it with fire and slew the Canaanites that dwelt in the city, and gave it for a portion unto his daughter, Solomon's wife" (I Kings, ix, 16).

Two tables which have lately been found give evidence of an Assyrian occupation of Gezer. Gezer had varying fortunes during the wars of the Jews and the Syrians. About 160 B. C. it was captured by the Syrians and afterwards recaptured by Simon Maccabæus, the great high priest, who fortified it, and built himself a dwelling place, which has lately been discovered. The history of Gezer stretches on through Roman, Crusader, and Arab periods.

From the excavations we get an idea of the primitive religious customs which Israel met with on their entry into Palestine, the idolatry and the moral abominations, and from the discoveries made it is easy to see why the worship of the High Place was so fiercely denounced. The evidence of the wholesale sacrifice of children, the images found testifying to the licentiousness pervading the whole worship, the evidences of bodies sawn asunder, and other savageries, all throw a lurid light on the "iniquity of the Amorite."

We next reach Jaffa, whence we embark on our way to England, and thus our delightful tour is brought to an end.



JERASH. STREET OF COLUMNS



AMMAN FROM CITADEL



AMMAN. THE AMPHITHEATER



RUINS OF OLD CHURCH AT AMMAN



OLD MOSQUE AT AMMAN



HEBRON FROM THE NORTHWEST



THE MOSQUE, HEBRON, WHERE THE PATRIARCHS WERE BURIED



BEIT JIBRIN, CHURCH OF ST. ANNA

THE UTILIZATION OF VOLCANIC STEAM IN ITALY ¹

[With 2 plates]

The increased desire for economic independence that accompanied the growth of national sentiment during the war has been shown very clearly in the intensified study and exploitation of natural resources; and the welkin is still ringing with cries of "increase production," "back to the land," and "keep the home fires burning." Examples of this world tendency are apparent everywhere; in central Europe, particularly, brown coal, water power, and minerals have been greatly developed; in tropical countries useful vegetable products have been increasingly exploited; and in many lands the rush for petroleum has gathered momentum. Very little, however, has been heard as yet of attempts to utilize the interior heat of the earth, which many believe to be one of the most important potential sources of energy. Only in Italy has a definite and successful effort been made in this direction, namely, by utilizing the natural steam which emerges from the earth in volcanic districts. The jets of steam ("soffioni") and the pools of water, formed in small craters and maintained at boiling temperature by natural steam ("lagoni"), have been known for centuries, but for long were regarded by the peasants as manifestations of unseen and unfriendly powers. The discovery in them of boric acid in 1790, the extraction of this acid on a commercial scale since 1818, and in particular the recent pioneer work of Prince Ginori Conti, in association with the Società Boracifera di Larderello, have completely transformed the picture, and revealed a source of wealth which may play an important part, not only in the future industrial development of Italy, but also in that of other countries that are blessed—and at times cursed—with volcanic activity.

The district which has been selected for study and exploitation forms, roughly, an elliptical area of about 2.5 square miles, lying south of Volterra and from 40 to 50 miles south-southwest of Florence. In this part of Tuscany works for generating electrical power and for producing boric acid and other chemicals have been erected at Larderello, Castelnuovo, Sasso, Monterotondo, Lago, Lustignano, Sarrazzano, and to the eastward at Travale. The works are situated at the bases of hills dividing the valleys of the rivers Cecina and Cor-

¹ Reprinted, by permission, from *Nature*, Jan. 12, 1924.

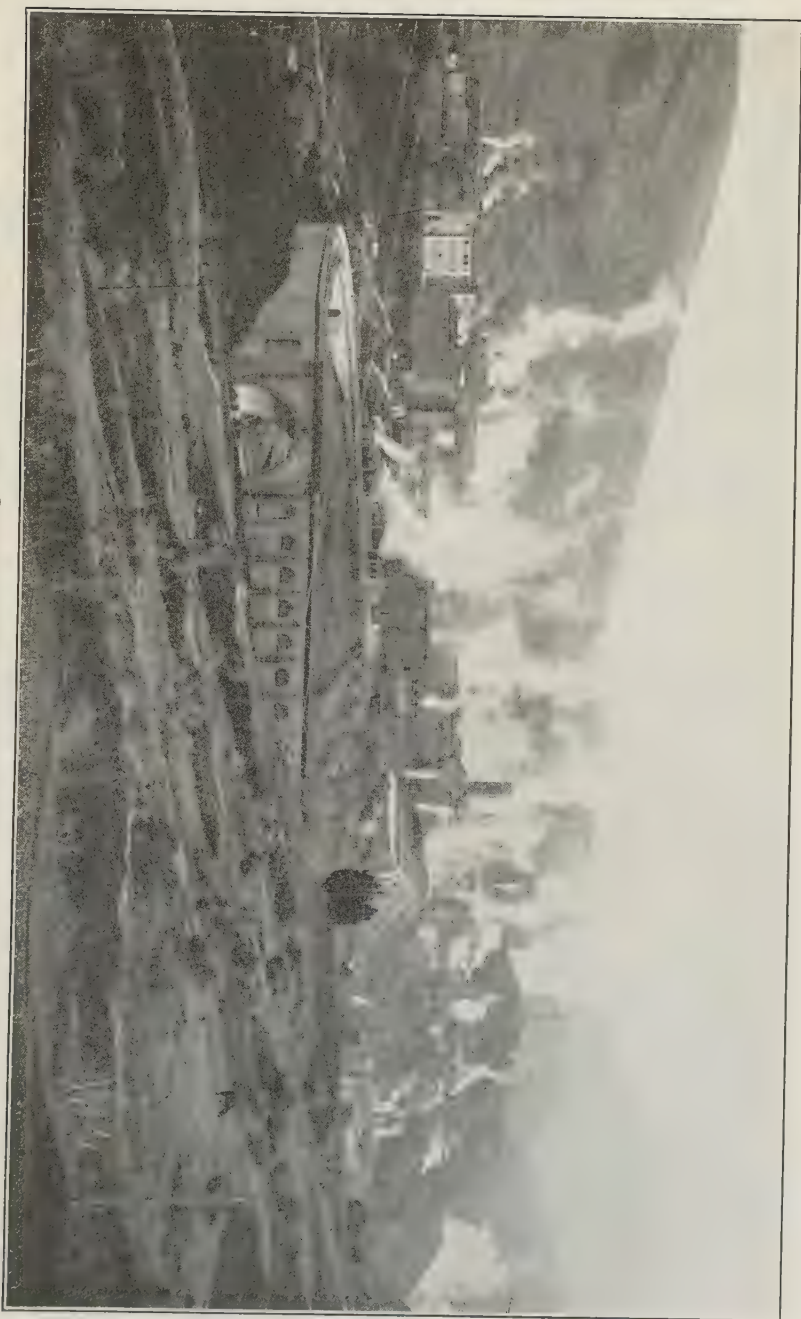
nia, and the roads are good, though winding. The volcanic nature of this district is shown by stretches of arid soil, the presence of many "soffioni" and "lagoni," and by the occurrence in their vicinity of sulphur, crystals of calcium carbonate, with pseudomorphous growths of gypsum, larderellite (ammonium borate), and sassolinite (orthoboric acid).

For industrial utilization the supply of steam from "soffioni" is not sufficient, and hence bore holes, 16 inches in diameter and from 200 to 500 feet deep, are sunk and protected from caving by iron tubing. The steam issues at an average pressure of 2 absolute atmospheres, and at a temperature varying from 100° to 190° C., friction against the walls of the bore causing much of the superheat. Recent drillings have released steam at a considerably higher pressure, and in quantities up to 60,000 kilograms (59 tons) per hour. At Larderello the actual available output is above 150,000 kilograms per hour from 135 bore holes, and generally there is abundant evidence of enormous untapped supplies. The steam, which Prof. R. Nasini has shown to be radio-active, contains an average of 0.06 per cent of boric acid, with a maximum of 0.1 per cent, and about 4 to 6 per cent by weight of gases, mainly carbon dioxide (over 90 per cent), but also hydrogen sulphide, hydrogen, methane, oxygen, nitrogen, ammonia, argon, and helium.

The first attempt to produce power from natural steam was made in 1897 by using it to heat water in a boiler and feeding a reciprocating engine with the pure steam. In 1905, Prince Conti fed steam direct from a "soffione" into a piston engine, and the result was so successful that in the following year a larger engine was used, and the steam generated was made to drive a dynamo for lighting the works. In 1912 it was decided to erect a 250-kilowatt turbo-generator to be worked with natural steam, but owing to fear of corrosion of the turbine blades, and the difficulty of obtaining a good vacuum in the condensers, on account of the presence of the gases mentioned above, this intention was abandoned. Intermediate boilers or evaporators were therefore constructed and used.

The present large power plant at Larderello was first operated in 1916, and comprises evaporators, turbo-generators, condensers, and transformers. The evaporators employed, until recently, consisted of vertical aluminum tubes inclosed in a shell of sheet iron; natural steam circulated round them and the water to be evaporated through them, this water being taken from the condensers or from that formed by condensation of the natural steam.

According to a paper which was read by Prince Conti at the Catania meeting on April 5-11, 1923, of the Italian Association for the Advancement of Science, this type of evaporator has been re-



GENERAL VIEW OF LARDERELLO



FIG. I. NEW WHARF, HOPEWELL. HIGH WATER



FIG. IA. NEW WHARF, HOPEWELL. LOW WATER

PROPOSED TIDAL HYDROELECTRIC POWER DEVELOPMENT OF THE PETITCODIAC AND MEMRAMCOOK RIVERS¹

By W. RUPERT TURNBULL, F. R. Ae. S.

Rothsay, New Brunswick, Canada

[With 1 plate]

HISTORICAL

We should run over first and in a brief manner the tidal developments and proposals of the past, so that you will be led, as I have been, to think that the first large tidal development in the world will probably be carried out at Hopewell, the little village that lies closest to the tidal estuaries, the Petitcodiac and Memramcook, where nature has formed two great natural reservoirs, with the exception of the dams that must be built to complete them.

Old charters show that tidal power was used in England for grinding corn as early as the eleventh century and tidal mills have been in operation for the same purpose from that time to the present day.

The following extracts are taken from an excellent article by W. C. Horsnail that appeared in *The Engineer*, London:

No record exists showing how the earliest tide wheels were arranged, but particulars are available of several mills which were erected in the eighteenth and nineteenth centuries. In the earlier historic mills no attempts were made to produce a fall, the power being obtained from the flow of the water into and out of the pound. To develop power in this way a wheel similar to the paddlewheels of steamships was used, but with a reversed action; that is to say, the flow of water drove the wheel. This arrangement entailed the raising and lowering of the wheel to suit the rise and fall of the tide, as only the bottom floats could be immersed if the best results were to be obtained.

A corn mill at one time existed at East Greenwich which was driven by tidal power in the way we have described. The pound had an area of about 4 acres and the wheel measured 11 feet in diameter by 12 feet long. The power was transmitted by a bevel gear at either end of the water-wheel shaft, the pinions being free to slide up and down two square vertical spindles. The water wheel and bevel gears were mounted upon a frame

¹ Revision of paper read at the professional meeting of the Engineering Institute of Canada, St. John, New Brunswick, Sept. 11, 1919. Reprinted by permission from the *Journal of the Engineering Institute of Canada*, October, 1919.

which was caused to rise and fall to suit the tides, and the power was transmitted by either bevel wheel according to which way the water wheel was running, the other bevel pinion being thrown out of gear. By these means the machinery in the mill was always driven in one direction, in spite of the reversal of the water wheel at each turn of the tide.

The movable frame, with the water wheel and gear, weighed some 20 tons and the bottom of it was extended to form a kind of shutter, which filled up the opening underneath the wheel race, all the water flowing into or out of the pound being thus compelled to pass through the wheel.

Another type of wheel was devised to overcome the drawback of having to move up and down with the tide. This wheel was fitted with hinged floats, which arranged themselves across the stream at the bottom of the periphery, while they traveled through the water edgeways during the remainder of each revolution. With floats of this type the wheel was fixed, and the tide gradually rose over it until in some cases complete immersion took place.

An arrangement of the sluices was also adopted to compel the water to pass through the wheel in the same direction, whether flowing in or out of the pound, thus doing away with the need for reversing gear between the water wheel and the machinery to be driven.

These wheels must have been very inefficient, as the loss of power caused by the drag of the upper portion when covered was serious, and the design was soon discarded.

Following these earlier mills came the more recent examples, many of which are still in existence, while a few of them may be seen in operation. The older mills aimed at using the current of water caused by tidal action and advantage was taken of the flow in either direction. The more modern tide wheel is arranged to operate with considerable fall, and only develops power when the water is flowing out of the pound.

The undershot wheel with straight radial floats is usually adopted, and the mill is started at half ebb or a little later, work being continued for about five hours, or until the water rises under the wheel and chokes the tail race. These arrangements give only five hours of working during each tide.

Listing the tidal mills that actually exist, we have a mill at Woodbridge of 10 to 12 horsepower, one at St. Osyth of 20 horsepower, and one at Walton-on-the-Naze of 85 horsepower. These are all small powers, working on a low range of tide and with only a single, small, natural reservoir that allows of only a partial use of the tidal power for a comparatively short period of time, but Mr. Horsnail shows that if modern turbines were installed at the plant at Walton-on-the-Naze and the power was used to develop electricity, instead of grinding corn, it would show up as a commercial development somewhat better than gas power, in spite of the heavy outlay for storage batteries which would be necessary at a plant situated as Walton is.

The number of proposals for tidal plants is very considerable, and while I think I should not take up your time by discussing all of them, it is worth while to examine a few of the more serious ones.

Mr. James Saunders discussed, in the Engineering Review of London, three great plants for developments in England, viz, at Chichester Harbor, at the Menai Straits, and in the Bristol Channel. But in each case either the head of the water was too low or the cost of forming the artificial reservoirs was too great to make the proposals commercial at the present time. His most promising scheme is that for the Bristol Channel, where the tidal head is quite sufficient for successful operation, but where the cost of forming the great artificial reservoirs that would be here required is prohibitive in view of the power obtained. The total cost of the plant figured out at \$47,000,000 and the horsepower at 240,000, so the cost per horsepower would be \$196.

C. A. Battiscombe, before London Society of Engineers, also made a tidal proposal for the Bristol Channel, but his cost works out at \$237 per horsepower; and while neither of these figures would be too high for commercial developments in some localities, they are too high to interest English capital, for England is still a country of cheap coal and in examining any hydroelectric development we must constantly keep in mind the cost of power from other sources.

Mr. Boving has proposed a tidal plant for the River Dee, but no estimates of costs are given; and coming nearer home, there have been numerous proposals for obtaining power from the tides at Sackville, at Cape Split, and at the Reversible Falls of St. John.

Now to get *continuous* power at any of these sites, it would be necessary to form large artificial reservoirs, and the formation of such reservoirs is so costly that these proposals are not, at present, commercially feasible.

DESIDERATA FOR A TIDAL PLANT

The three great desiderata for a tidal plant are: First, that there should be sufficient height of tide to obtain a good head; second, that there should be two natural reservoirs of large size so that continuous power can be obtained; and, third, that the power plant should be central to the population that would be served.

And it is these three desiderata that lead us to suppose that the first great tidal development in the world will take place at Hopewell. Here we have two large reservoirs almost completely formed by nature, we have a tide which is exceedingly regular and that ranks among the highest tides in the world, with a spring rise of 45 feet, a neap rise of 38 feet, and a normal neap range of 32 feet, and we have this power centrally located to a present population of 250,000 who are literally starving for cheap electric power, with no other hydroelectric developments in sight, except small ones and those that

are too distant from the centers of population to make their development commercial at the present time.

I have examined many other sites for tidal power, in those parts of the world where the tides are sufficiently high to make tidal power at all possible, and I am firmly convinced that we have at Hopewell, the site that is most promising at the present time, from a commercial standpoint.

HOPEWELL PLANT

To give you some idea of the height of the tide at Hopewell, I will show some photographs (pl. 1, figs. 1 and 1a) that were taken this summer of the Government Wharf at Hopewell at high water and at low water. This wharf, which is 55 feet high, is the only one to reach low water at ordinary and subnormal neap tides; it does not reach to low water at spring tides, and all other wharves in the neighborhood are high-water wharves, and are only reached by the water when the tide has risen about half its height.

We will now discuss the principle which I have proposed for obtaining continuous power from these great tides, and I will draw your attention to this map of the two tidal estuaries, the Petitcodiac and the Memramcook rivers (fig. 2). This map shows the general trend of these rivers, and their confluence at Hopewell, and it also shows the fresh-water drainage areas of the two rivers—which, although a minor item as compared to the great volume of salt water that flows up and down these rivers, should still be borne in mind in reviewing this proposal.

The dotted lines show the respective drainage areas approximately, and these have been calculated out to show a drainage basin for the Petitcodiac of 784 square miles and for the Memramcook of 134 square miles or in the ratio of nearly 6 to 1. (The heavy black line is a county boundary.)

At present the flood tide makes up these rivers for approximately six hours and then turns and flows back into the bay for six and one-half hours, and this map also shows the approximate limits of this flow, above which points the streams are fresh water.

The next (fig. 3) shows a scale chart of the confluence of these two rivers, at Hopewell, the proposed location of the dams that will be necessary to control the waters, the depths of water at low tide, etc.

The western dam would be 4,900 feet long, the eastern dam 4,800 feet long, and a wing dam of 900 feet would connect the two, and it would, of course, be part of the plan to have a highway and trolley line (operated by the plant) over the tops of these dams connecting up the two main shores and the long peninsula that makes down between the two rivers.

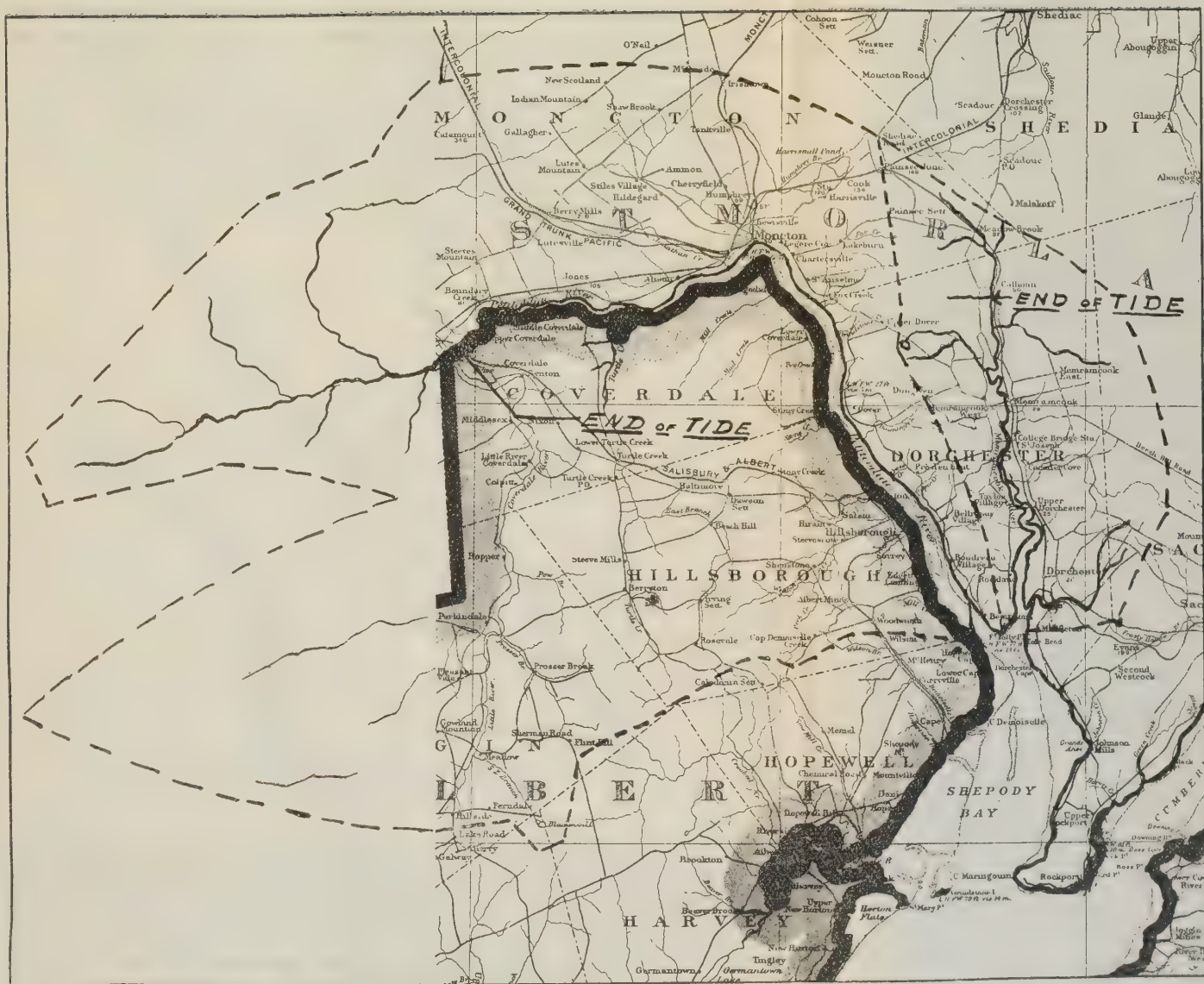
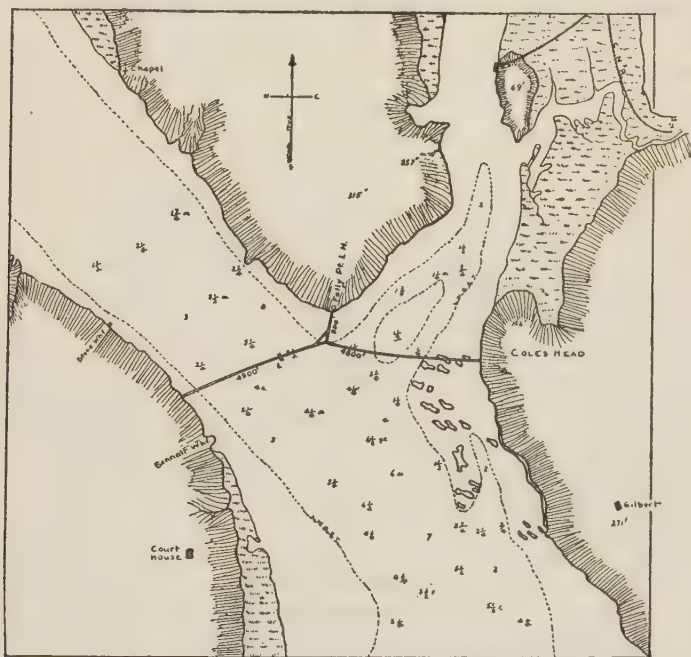


FIG. 2.—Map showing the watershed of the Petitcodiac and Memramcook Rivers

This highway would only be a matter of local benefit, but it would be of immense benefit to the building up of this locality. At present Hopewell can only be reached from Coles Head by a little ferry that can only operate for a few hours near high tide; the Petitcodiac is only bridged at Moncton, 19 miles above Hopewell; the Memramcook was bridged at Upper Dorchester, 5 miles above Hopewell, but this bridge is now gone, and the Government is at present making borings for a bridge to take its place that will cost about \$1,000,000.

At present Hopewell, Hillsborough, and the big peninsula are hard places to get into, and still harder places to get out of, and yet they



Confluence of Petitcodiac & Memramcook Rivers

FIG. 3

are regions of great mineral resources that only require, but still await, development. The figure shows a lock in the western dam, through which vessels could be passed at any suitable time of the tide, on their way up and down the Petitcodiac, and Hillsborough and Moncton would be provided with deep-water harbors instead of the mud flats which they at present enjoy at every low tide. The gates of the lock would naturally be swung by electric power furnished from the near-by power house.

The proposal provides for making the Petitcodiac a high-level basin in which the water would always be high, and be replenished at every high tide, while the Memramcook River would be a low-level

basin to be partially filled from the high-level basin and be always emptied during the latter part of the ebb tide. This arrangement would also admirably suit local conditions, for the Memramcook is exclusively a farming district in which much time and money is at present expended in excluding the tides by means of dykes, and I have been informed by farmers of this valley that they would only wish to have the salt water flood their lands about once in 10 years for the purpose of fertilizing them. The navigation of this river is practically nil, so it would hardly be necessary to provide any lock in the eastern dam—two or three times during a summer a small vessel will

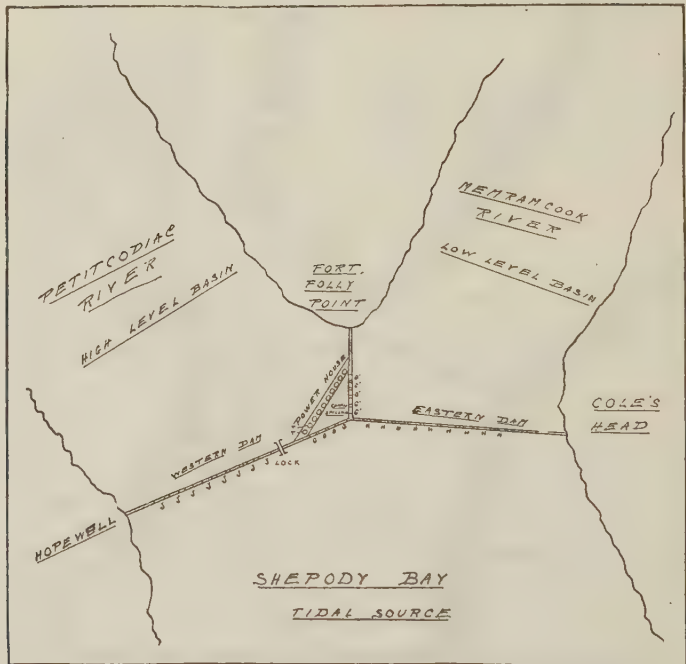


FIG. 4.—Illustration of principle for obtaining continuous power from the tides

lie at the Dorchester Island wharf for the purpose of discharging goods, but these could be as well discharged below the dam and the power company could well afford to pay for the short extra haulage.

I will now call your attention to the next figure (No. 4) which illustrates—in scheme but not to scale—the principle that I employ to get continuous power from the tides, with a varying head to be sure, but with the water always passing through the turbines in the same direction and always with a head sufficient to make turbine operation successful. The diagram shows the confluence of the two rivers, with the necessary dams and gates to control the flow—the gates J, J, etc., in the western dam would be automatic flap gates opening upstream, allowing the high-level basin (the Petitcodiac) to fill

at every high tide and the gates H, H, etc., of the eastern dam would be automatic flap gates opening downstream, and allowing the low-level basin (the Memramcook) to empty on every ebb tide.

The gates G, G, etc., and G^1 , G^1 , etc., would be of the nature of lock gates; they would be operated by electric motors, driven by the power plant itself, and be under the control of the attendants, who would open them and close them in accordance with the height of the external tide at stated times that can be fixed for months in advance directly from the tide tables.

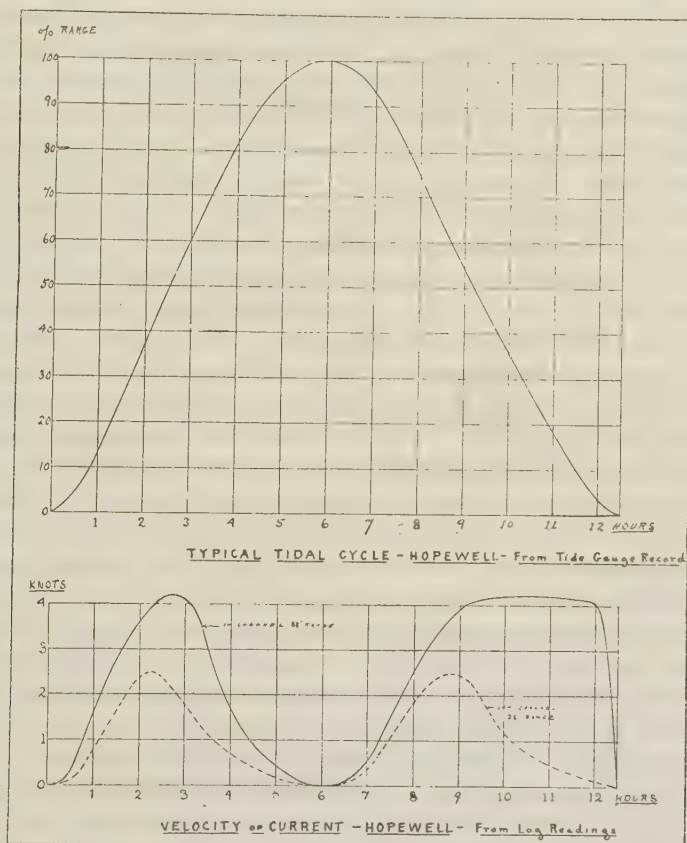


FIG. 5

The power house is represented as a long building, with turbines T, T¹, etc., extending diagonally from the wing dam to the western dam, and these turbines discharge continuously from the high-level basin into the common triangular tailrace. Let us now follow through a cycle of operations from low tide to the following low tide, remembering that the high-level basin was filled automatically at the last high tide and that the low-level basin has just been emptied during the ebb tide through the gates in the eastern dam.

OPERATION

Beginning with low tide, we may at first leave gates G, G, etc., open and allow the water from the tailrace to discharge directly into the tidal supply (Shepody Bay), but the head will gradually decrease as the tide rises, and at about $2\frac{1}{2}$ hours rise the attendants close gates G, G, etc., and open gates G¹, G¹, etc., allowing the discharge from the tailrace to enter the low-level basin; into this the tailrace will continue to discharge for about $6\frac{1}{2}$ hours, or through the last $3\frac{1}{2}$ hours of flood tide and through the first 3 hours of ebb tide, after which time the water in the low-level basin will have so risen, and the water of the tidal supply will have so dropped, that it will now be profitable to close gates G¹, G¹, etc., and open gates G, G, and once more allow the discharge to occur directly into the source of tidal supply and give the low-level basin time to again drain out on the ebbing tide. I think you will at once grasp from this the simplicity of the system itself, but in order that we should study more fully one of the engineering problems involved I will call your attention to the next figure (No. 5), the typical tidal cycle at Hopewell; this curve shows a copy, in per cent of range plotted against time, of an actual tidal record, obtained at the ordinary neap tides by the tide gauge established in 1919 at Hopewell by the Canadian Tidal Survey, and furnished to me by the courtesy of Mr. H. W. Jones, of that department. You will note how exceedingly regular the tide is and how little affected by estuary flow, and this is one of the great advantages of Bay of Fundy tides in general. At certain places in the world the diurnal inequality becomes so great that for several days there is only one tide in 24 hours, and at Southampton there is a second high water occurring about 2 hours after the first.

In dealing with the question of tidal power at Hopewell we must remember that although the tide is regular in type, nevertheless the *range* of the tide and not the *rise* is the limiting factor of our power calculations, and it becomes necessary to establish and work on what might be called a "standard" range. For this purpose I have analyzed approximately the ranges that will occur in the course of a year. I call spring tides those whose range exceeds 42 feet; they occur about 15 per cent of the time, and I think no attempt should be made to utilize them especially; I call subnormal neap tides those whose range is less than 32 feet; they also occur about 15 per cent of the time, and some means, which are discussed later, would need to be employed to avoid the impairment of our "standard" amount of power.

All other tides I call ordinary neap tides, with a range at Hopewell of 32 feet to 42 feet; they occur about 70 per cent of the time, and it is the lower range of 32 feet which I think we should adopt as our

"standard" range, and the curves and estimates that follow are based on this range of 32 feet.

We will now return to the discussion of the principles involved in the proposed plant, and I will ask you to examine the next figure (No. 6), which shows a tidal cycle at a "standard" range of 32 feet, with an assumed drop in the high-level basin of 6 inches per hour, and the level changes that will occur in the two basins with the opera-

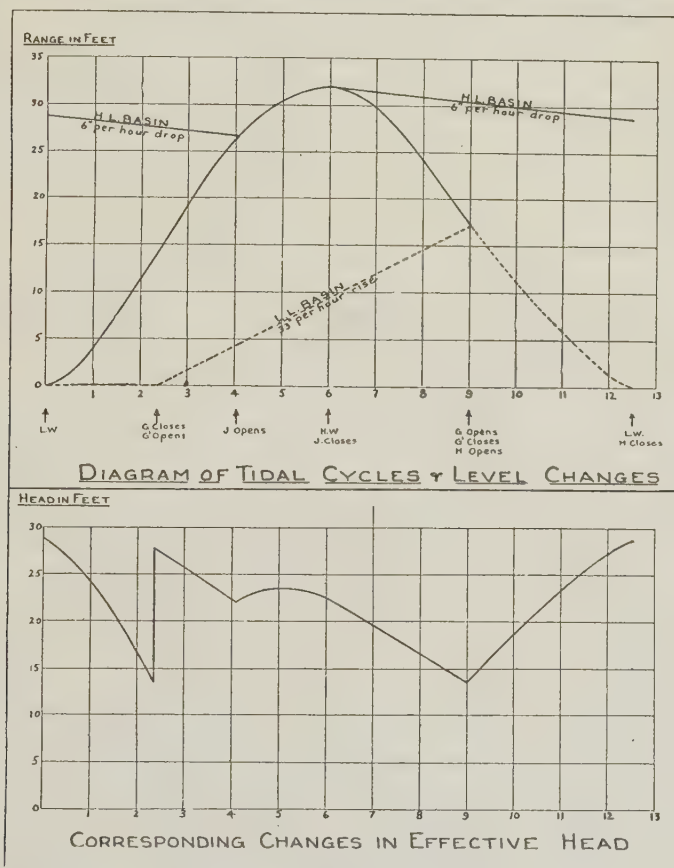


FIG. 6

tion of the plant, as before described. If the conditions at Hopewell were better, the ratio of effective areas would be as 2 to 1 for the high and low level reservoirs, but unfortunately this is not the case, for the Petitcodiac contains an effective area of about 330,000,000 square feet, while the Memramcook has only about 60,000,000 square feet, so that the ratio is about $5\frac{1}{2}$ to 1; thus while the water in the Petitcodiac is dropping 6 inches per hour the water in the Memramcook is rising five and one-half times this, or 33 inches per hour, and

these level changes are illustrated in the diagram, while the changes in effective head on the turbines is plotted immediately below.

Full lines above show the level changes of the high-level basin; dotted lines below, those of the low-level basin. Starting at low

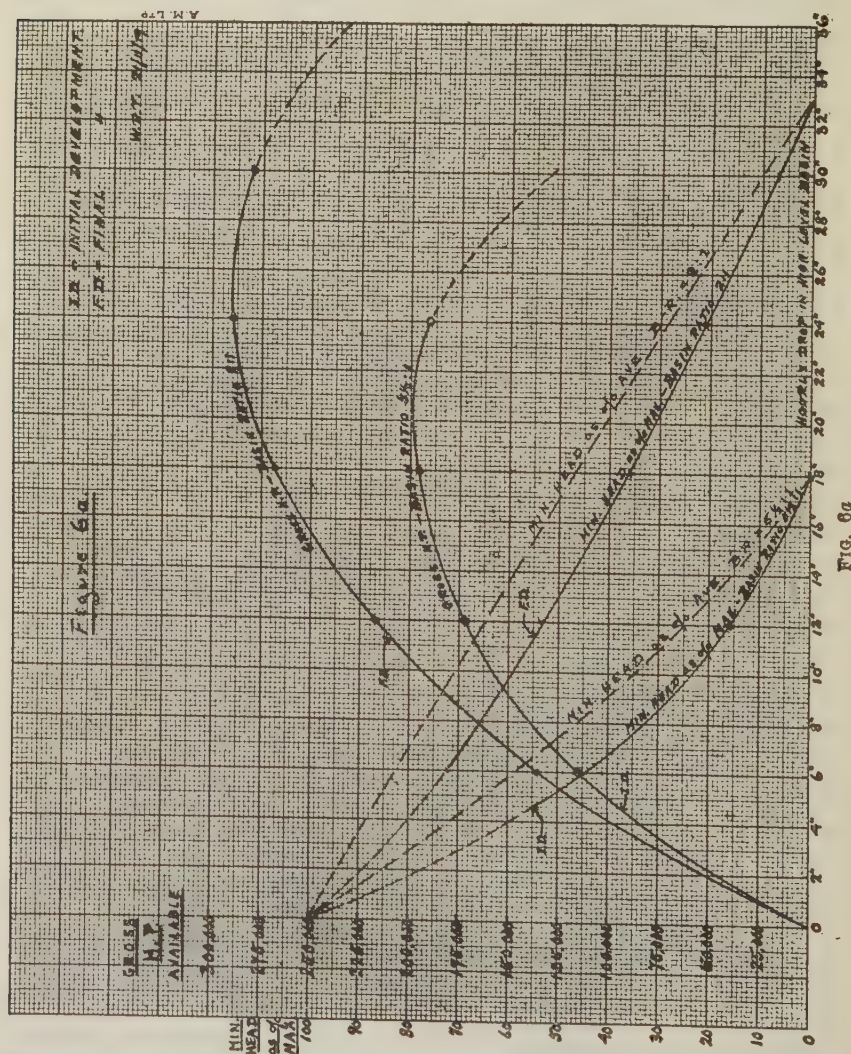


FIG. 6a

water, you will note that for 2.35 hours the level of water in the low-level basin is unchanged, for the water from the tailrace is discharging into the tidal supply direct, but during this time the head is decreasing from $28\frac{1}{2}$ feet to $13\frac{1}{2}$ feet when it becomes expedient to discharge into the low-level basin, when the head will at once rise to $27\frac{1}{2}$ feet.

After this for $6\frac{1}{2}$ hours the low-level basin will rise, but the high-level basin will also rise after 4.1 hours (as the flood tide will then be filling it for 1.9 hours) and we have the head decreasing from $27\frac{1}{2}$ feet to 22 feet, but afterwards increasing to $23\frac{1}{2}$ at 5.2 hours.

After this the head will gradually decrease to $13\frac{1}{2}$ feet at 9 hours, when, the tide in the external bay having sufficiently ebbed, the water from the tailrace will be again discharged into it and the head will steadily rise to its previous maximum of $28\frac{1}{2}$ feet at low tide, as shown by the curve of heads.

The average head in this case from low tide to low tide works out at $22\frac{1}{4}$ feet.

POWER AVAILABLE

The selection of a 6-inch drop per hour in the high-level basin is merely for the purpose of an illustration, but other drops may be considered, and in order to ascertain *the most suitable drop* for the initial and final developments (which are referred to later) we must consider the limits of good turbine operation, with variable heads, and plot out the gross horsepower curves against various hourly drops under the conditions, first, of the initial development (here taken at 90,000 horsepower, and the present basin ratio of 5.5:1) and second, of the final development (here taken at 200,000 horsepower, and the improved basin ratio of 2:1).

These data have been worked out (fig. 6a) for both basin ratios and the respective areas, and when we select an initial development of 90,000 horsepower (which is that indicated by the present population) we note that this corresponds to an hourly drop in the high-level basin of 4.4 inches, a minimum head, as per cent of maximum, of 55 per cent, and a minimum head, as per cent of average, of 69 per cent. And for a final development of 200,000 horsepower, with basin ratio improved to 2:1, the hourly drop would be $10\frac{1}{2}$ inches, the minimum head, as per cent of maximum, 56.7 per cent, and a minimum head, as per cent of average, of 68 per cent. The actual heads in feet for the two developments are given in Figure 6b, plotted against the time of a complete cycle, and we then have for a comparative table the following:

	Initial development, 90,000 horsepower	Final development, 200,000 horsepower
Maximum head.....feet.....	29.6	26.3
Minimum head.....do.....	16.25	14.9
Average head.....do.....	23.55	21.94
Minimum, as per cent of maximum.....per cent.....	55	56.7
Minimum, as per cent of average.....do.....	69	68

It will be noted from horsepower curves (fig. 6a) that up to certain maxima (198,000 for the 5.5:1 basins and 290,000 for the 2:1 basins) the available horsepower increases with an increase in the hourly drop allowed in the high-level basin, but it must be borne in

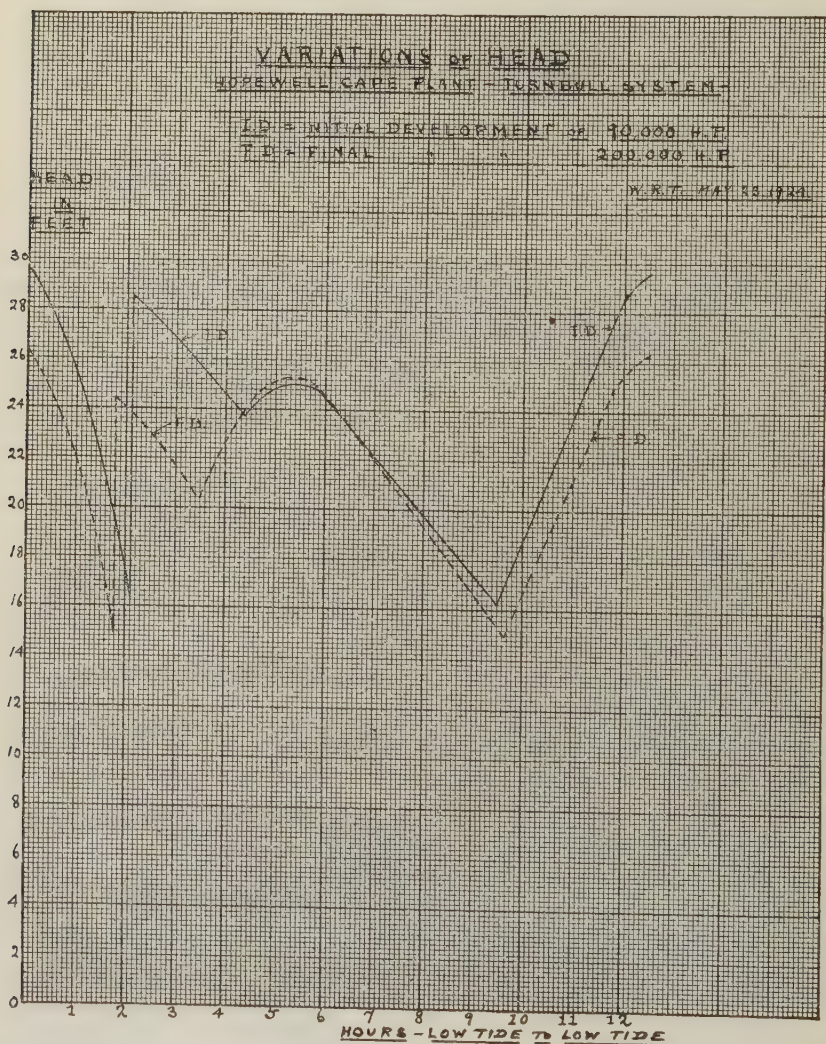
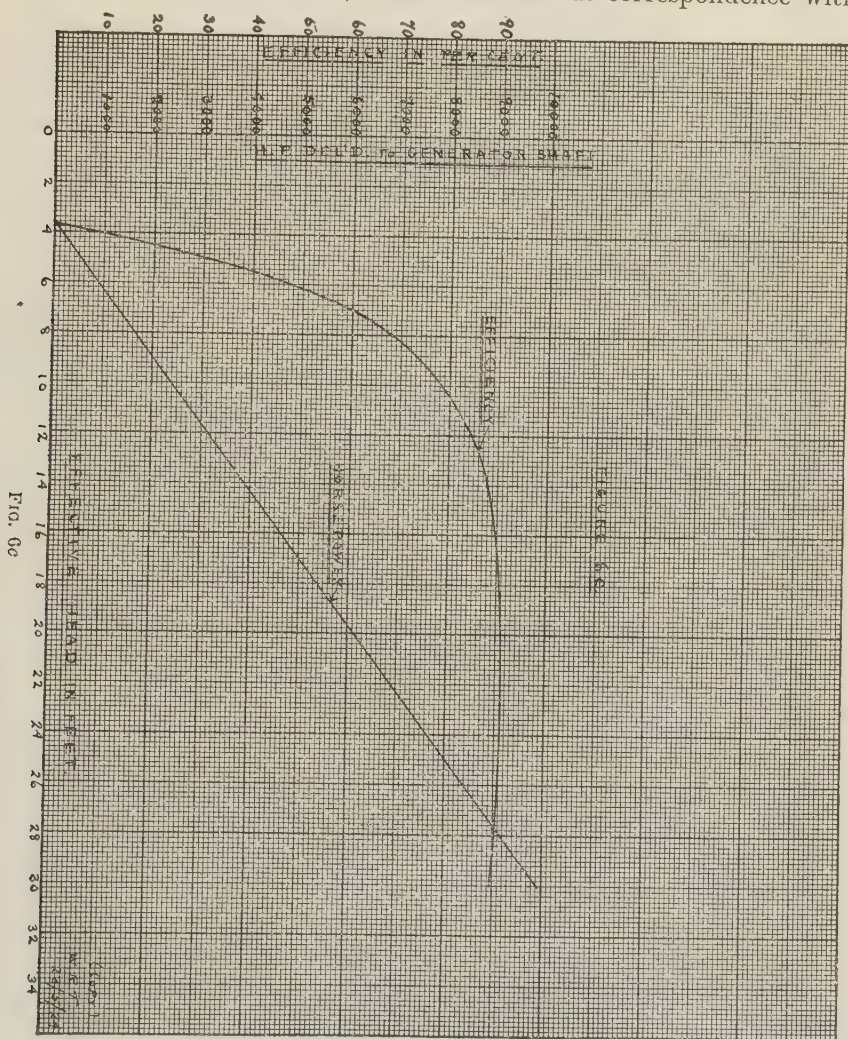


FIG. 6b

mind that as the hourly drop increases the maximum head decreases, and the minimum head decreases more rapidly still; and we must therefore select cases, such as has been done in the above table, that can be successfully met by turbine operation.

TURBINES

The best type of turbines to meet the constantly varying heads of a tidal plant is open to a considerable amount of discussion, and it is quite possible that special designs would be required to give really the best results. However, I have carried out correspondence with



several turbine manufacturers, and I am assured by them that turbines can be supplied of present design and with high efficiency that can satisfactorily meet the conditions given in the above comparative table.

In correspondence with the I. P. Morris department, of William Cramp & Sons, Philadelphia, they have recommended a high-speed

propeller-type turbine (Moody diagonal propeller type), and we consider this type here to afford a concrete example, the following data being supplied by the company with special reference to this particular type of turbine and the Hopewell conditions as to head, etc.:

Item	Initial 90,000 horsepower	Final 200,000 horsepower
Moody diagonal propeller type:		
Diameter.....	15 feet 9½ inches.....	15 feet 9½ inches.
Unit spacing.....	51½ feet.....	51½ feet.
Speed (r. p. m.).....	80.....	80.
Rating, average head.....	7,450.....	6,450.
Number of units, average head.....	12.....	31.
Horsepower, maximum head.....	9,850.....	8,500.
Horsepower, minimum head.....	4,700.....	4,200.
Number of units, minimum head.....	19.....	48.

Curves of the horsepower (average head case) and efficiency of these turbines are given in Figure 6c, and it will be noted that the efficiency is high over a wide range of head, and that we might expect a very good average efficiency from this type of turbine.

The above data are tentative, but give a good idea of what can be done by good low-head turbines, even over a wide range of head variation.

INITIAL AND FINAL DEVELOPMENTS

The initial installation called for at the present time by the existing population would be about 90,000 gross horsepower, and we note from Fig. 6a that this corresponds to an hourly drop of 4.4 inches in the high-level basin. Now, while the population grew and the demand for electricity increased from 90,000 upwards, we could steadily be improving the ratio of the two basins, and thus greatly improve our power output, up to, say, 200,000 horsepower.

To improve this basin ratio to a better condition, in which the Memramcook would have half the effective area of the Petitcodiac, I propose to use electric shovels and an electric tramway, both operated by surplus power from the initial installation, expropriate, by Government charter, the low-lying farms of the Memramcook Valley at a fair and equitable rate, and shovel out the basin according to power requirements, removing the material by the electric railway and dumping it below the eastern dam, where it would be largely carried away by the tide, or could be formed into a useful embankment—wharf, railway terminal, or the like.

A cheaper method of enlarging the Memramcook basin might be to employ hydraulic excavation methods when this basin was being emptied, the water for this system being pumped when there was

surplus power from the plant to the high levels that exist on the peninsula (315 to 570 feet), there stored in reservoirs, and then used at suitable times, with these high heads, by means of a pipe line to the parts to be excavated.

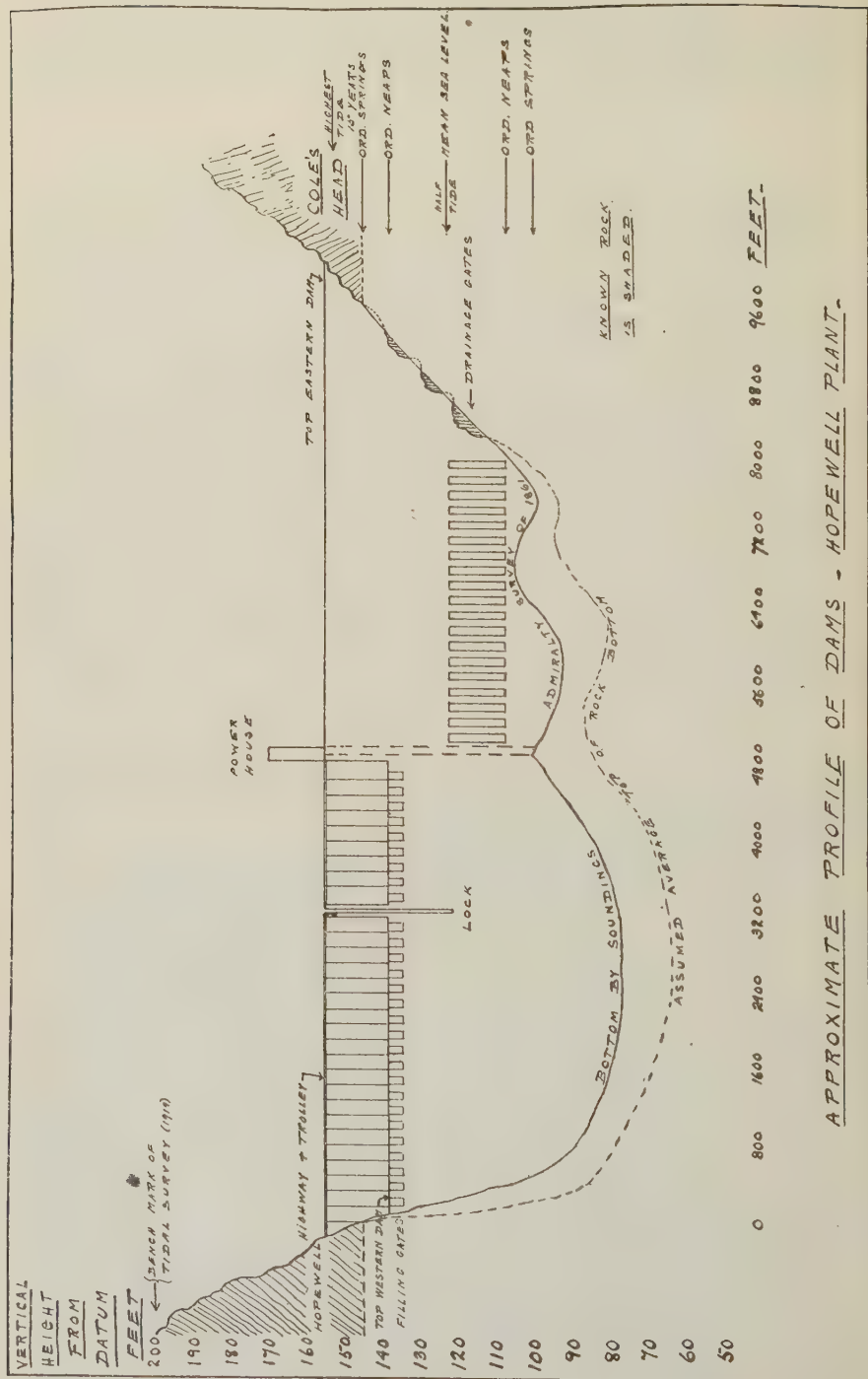
TYPE OF DAM

The next figure (No. 7) shows the approximate profile of the western and eastern dams; since it would not be policy to attempt to get the extra power that spring tides would give, the western dam need only have the height of high water, ordinary neap tides, but the height of the eastern dam would have to be carried up beyond the highest probable spring tides to insure that the low level basin was never flooded at high tide. The figure shows this dam carried 3 feet higher than the highest spring tide that occurred during a period of 15 years. As before mentioned, the tops of the dams could be utilized as highways and would thus be of invaluable local benefit, and a light steel structure is indicated on the western dam for this purpose. The masonry width called for by the calculations would not be sufficient for a roadway, but a light steel structure could be winged out on top of the dams and made of sufficient width to carry a good roadway, an electric tram, and the power-transmission lines that would go both west to St. John and east to Halifax.

The flap gates for filling the high-level basin and emptying the low-level basin are indicated in the sketch profile. They should present no engineering difficulties, but they should be designed of sufficient size to readily pass the full volume of water required by the final and maximum development.

We now come to the question of the river bottom and the location of rock for a good dam foundation, and I regret that I can not give any exact data. In the summer of 1919 I went twice to Hopewell, but could only obtain indirect evidence as to the depth of the rock under the muddy beds of the two rivers. The full line of the profile shows the depth of the top of the mud, according to the Admiralty chart, and there is strong presumptive evidence that the top of the rock does not lie more than 15 to 20 feet below this. Where the "new wharf" was built at Hopewell the mud soon washed out for a depth of 12 feet, when hard bottom was reached, and the outcropping of ledge rock at the mouth of the Memramcook, as shown on the chart and profiles, indicates the rock bottom for a quarter of a mile is very near the surface. The shores at Hopewell, Fort Folly Point, and Coles Head are all rocky, and the nature of all rock in this locality is the same, viz, shaley sandstone to pure sandstone sufficiently sound for making grindstones.²

² The water-power branch of the Dominion Government is to make borings and other investigations at the site of the proposed dam this coming summer (1924).



APPROXIMATE PROFILE OF DAMS - HOPEWELL PLANT.

As to the best type of dam to build at Hopewell, I feel that I should offer no opinion, for the question of dam design is an engineering specialty, and only an expert in this particular branch of engineering could decide the best type to adopt, and he only after a systematic line of borings were obtained along a proposed site. It has been suggested to me that a dam composed of hollow sections of concrete is a satisfactory and cheap type to build, the sections being built in a dry dock, floated into position, and then sunk by filling the interior with rock and gravel. However, I doubt if this is a well-proven system, and, as I say, the question of best type should be decided by an expert of long experience. Such estimates of cost that I have been able to make have been based on the cyclopean concrete type of dam. In considering the best type to build at Hopewell the question of the tidal currents would have to be considered, and while these currents are not very swift, when the great height of the tide is considered, nevertheless they should receive attention. From Figure 5 you will note some current measurements that I made by using a ship's log attached to an anchored boat. When the tidal range was 38 feet the channel current reached a maximum of 4.2 knots, and you will note that although the flood current soon dies out the ebb persists at near its maximum until almost the time for the next flood tide to begin. Out of the channel the current runs swiftly for much shorter periods, and the tidal current makes shoreward as the shores are approached until we often have currents at right angles to the main stream. The dotted curve shows some measurements taken rather off the channel, with a tidal range of 28 feet, and the maximum under these conditions was 2.6 knots.

SPECIAL PROBLEMS

Before leaving the engineering problems that are presented by this novel plant, I will mention three other items that should be considered.

The question of subnormal neap tides requires especial attention, for while my calculations are based on the least range, viz, 32 feet of ordinary neap tides, nevertheless there are certain tides which occur sometimes three days a month, sometimes five days a month, and sometimes not at all in a month, which have a lower range than 32 feet, and may sometimes have a range as low as 25 feet.

Now, if our plant were built and running at full capacity, with a range of 32 feet, there would be an impairment of the regular capacity whenever these subnormal neaps occurred, which is about 15 per cent of the time, and I think some provision should be made to deal with them adequately. One method might be to keep the turbines and generators well ahead of the normal demand and use these extra ones only during the subnormal neaps; another method would be to keep the Memramcook shoveled out, as already described.

well ahead of the future requirements and thus improve the average head; and yet another method would be to build a fresh-water dam, say, just below Turtle Creek, about 5 miles west of Moncton, in which fresh water would be impounded and released only to make up the deficiency in head at subnormal neaps. Still another method would be to employ auxiliary steam power to assist the water power during the water deficiency. One of the last two devices is nearly always resorted to in the case of ordinary hydroelectric plants situated on fresh-water rivers. In nearly all districts the amount of rainfall varies enormously during the different months of the year and the amount of run-off and discharge varies in a direct relation to the rainfall. As an example of this, the discharge at Grand Falls, on the St. John River, reached a maximum in May, 1909, fifty times greater than the maximum of October, 1909, and the mean discharge for the whole month of May was twenty times greater than the mean for October. In fresh-water rivers a certain power may run into thousands of horsepower in the spring, but be reduced to hundreds in the fall of the year, unless adequate means are resorted to to increase the deficiency of head.

In this matter a tidal power scores heavily over a fresh-water power. In the case of the fresh-water power neither the time nor quantity of a head deficiency can be predicted, but with a tidal power both the time and the deficiency are predicted by the tide tables several years in advance, and it would thus be much easier to provide for our head deficiency, which only, after all, amounts to 35 per cent in quantity and occurs only 15 per cent of the total time.

The best means of making up the deficit in the case of the Hopewell tidal plant would be best figured out in the final estimates as that one which would maintain the normal output at a minimum of cost.

The other two engineering items I wish to discuss are sediment and ice.

At the present time the never-ceasing current flow up and down the two rivers keeps the river stirred up, and the waters of both rivers show a considerable amount of sediment, and one would at first jump to the conclusion that this muddy grit, fine though it is, would produce much unusual wear on the turbines. However, what will happen as soon as the mouth of the Petitcodiac is closed by a dam? The mud in the water above the dam will undoubtedly settle, for it will have time to do so, and the water of the Petitcodiac will become clear. At present the water is never still, but with a dam the rise and fall would be reduced to a few feet and the current would be sluggish.

In a similar way the building of the dam would entirely alter the ice conditions. Once the dam was built, the whole river would freeze over in severe weather and the sheet of ice would rise and fall with

[illegible]

the water, just as it does in the St. John and similar rivers. Nevertheless, while the building of the dam was in progress the question of large masses of ice moving with the current should be given every attention, and quite likely some special method of cushioning the blows from ice might have to be devised.

POWER DISTRIBUTION

We will now turn to a consideration of the method of distributing the power available at Hopewell, and I will ask you to examine the next figure (No. 8) and note how centrally Hopewell is placed with reference to the centers of population of both New Brunswick and Nova Scotia.

The method of transmission carries with it no special problems, as we would undoubtedly use step-up transformers at the power house, transmit at about 66,000 volts with three-phase current, and use step-down transformers at the delivery points. All this system has been so thoroughly thrashed out, and is in daily use all over Canada and under Canadian winter conditions, that it has become practically "standard" and needs no special consideration here. The principal feature that should be considered in laying out the transmission lines would be one of expediency and proper return on the capital outlay of transmission lines and line losses. Undoubtedly a main line should go west to St. John, with power for all intervening towns and villages of any size, and undoubtedly a main line should go east and south to Halifax with power for Sackville, Springhill, Amherst, Truro, etc.; and also undoubtedly branch lines should go to Moncton, New Glasgow, and Stellarton, as the present population would warrant this. The extension of branch lines to St. Stephen, Fredericton, Newcastle, and Chatham is somewhat doubtful at present, but there are railways that well might be economically electrified toward all these points, and I have therefore included them in the preliminary estimate. I have prepared a table of the population that would be served by these lines, and the total works out at 250,000 inhabitants. With this as a basis, we should now estimate the probable per capita use and thus obtain an estimate of the proper size of plant for the initial development at Hopewell.

THE MARKET

When I prepared my first report on this subject it was submitted to the well-known firm of Sanderson & Porter, of New York—a firm who specializes in the control and management of some 60 hydro-electric developments—and their condensed criticism was as follows:

We think your proposal from an engineering standpoint is sound and it is the only scheme for utilizing tidal power that seems practical, but we are rather

in doubt as to whether the population served is sufficiently large to warrant the capital expenditure.

Now, this was in 1914, and I presume Sanderson & Porter based their opinion on the per capita use of hydroelectric power in the United States, which works out at 0.10 horsepower per inhabitant, according to the textbooks.

Since then, however, newer data have come to my hand, and if these data are accurate, as I presume they are, the complexion of affairs has changed and the Hopewell plant is a really *good commercial proposition* at the present time and needs only the governmental help accorded by a good charter.

The data that I speak of were published in Saturday Night about February, 1919, and are contained in a very interesting table which shows the per capita use of hydroelectric power for every Province of Canada and for the Dominion as a whole. It shows that British Columbia uses 0.36 horsepower per capita; Ontario, 0.288; Quebec, 0.267; and the whole of Canada, 0.206, and these figures are for *the total population*, and they should be increased at least 30 per cent for the per capita use of *population served*. It will thus be seen that Ontario, per capita served, is using about 0.37 and Quebec about 0.35, and I think we may properly assume that 0.36 would be used by the inhabitant of the Maritime Provinces as soon as you could give him really cheap electricity.³

On this basis, then, the population of 250,000 would require 90,000 gross horsepower, or, say, 45,000 horsepower at the delivery points: and I think the initial development at Hopewell should be for 90,000 horsepower,⁴ with every provision made for increasing the output as already outlined in this paper up to 200,000 gross horsepower, as the population and demand increased, as they undoubtedly would when cheap power was available.

COSTS

We now turn to the question of costs, and I have made an estimate of this as follows and in accordance with the textbooks on the subject:

Dam cost in cyclopean concrete

Western dam:

730 lineal feet, at equivalent height of 38 feet and \$210 per	
lineal foot-----	\$153, 000
4,100 lineal feet, at equivalent height of 65 feet and \$480 per	
lineal foot-----	1, 965, 000

³ The latest data show that since this was written (1919) the per capita use in Canada of hydropower has increased 22½ per cent and it is steadily increasing.

⁴ Probably now 110,000 horsepower in view of the above noted increase in per capita use.

Dam cost in cyclopean concrete—Continued

Eastern dam:

2,800 lineal feet, at equivalent height of 65 feet and \$480 per lineal foot.....	\$1,345,000
2,000 lineal feet, at equivalent height of 35 feet and \$180 per lineal foot.....	360,000

Wing dam:

900 lineal feet, at equivalent height of 30 feet and \$141 per lineal foot.....	127,000
Total cost (10,530 lineal feet).....	3,950,000

Since we will remain uncertain about the dam cost until borings are made, it will be best to allow \$4,000,000 in our preliminary estimates.⁵

The other items of cost can be more accurately estimated from the known cost of equipment in existing hydroelectric developments, and we have the following table of total estimated cost:

Dams, as per preceding estimate.....	\$4,000,000
Lock, in western dam.....	440,000
Sluices, gates, etc.....	450,000
Power house of steel and concrete.....	950,000
Turbines, generators, etc., at \$50 per gross horsepower.....	4,500,000
Transmission lines, etc.....	1,400,000
Preliminary dredging, dam, trench, etc.....	150,000
Promotion, engineering fees, etc.....	750,000
Auxiliary plant to supply head deficiency at subnormal neap tides, say.....	1,300,000
Total cost of initial development to produce 90,000 gross horsepower.....	13,940,000
Cost per horsepower developed.....	155

The cost for subsequent development is much less, relatively, for in the initial development full allowance has had to be made for the final development in all items except turbines, generators, and transmission lines and the cost of a full development of 200,000 gross horsepower would work out at about \$20,000,000, or \$100 per gross horsepower. In this estimate for final development the cost of shoveling and dredging the Memramcook farming lands—which would be necessary as previously shown—is not figured, for it would be undoubtedly good policy to start this work as soon as the power house was in operation and take the necessary cost out of the annual income.

To ascertain whether a hydro proposal is “commercial,” it is necessary, for any given locality, to compare the cost of developed horsepower with the cost of steam coal in the locality considered, and this relation for the Maritime Provinces is shown in Figure 9. In January, 1914, the wholesale price of steam coal was \$4.50 per long ton (at St. John, New Brunswick), and at that time and rate per ton for coal it was a paying proposition to develop a water power

⁵ Another method of obtaining approximate cost for dams was figured as follows: Approximate volume of all dams=465,000 cubic yards, less allowance for gates=70,000 cubic yards; net for dams=395,000 cubic yards. With concrete at \$10.50 per cubic yard, total cost of dams=\$4,150,000.

for \$132 per horsepower (this is an average figure for seven American developments)—at the present time the wholesale price of steam coal at St. John, New Brunswick, is \$8.68 per long ton, and it would therefore now be a paying proposition to develop a water power in this part of the world at the rate of \$255 per developed horse power, as shown in Figure 9.

According to my estimate of cost above, the initial development at Hopewell should be done for about \$155 per horsepower, and the final development for about \$100 per horsepower; and while the borings to be made this summer may determine the rock bottom at a

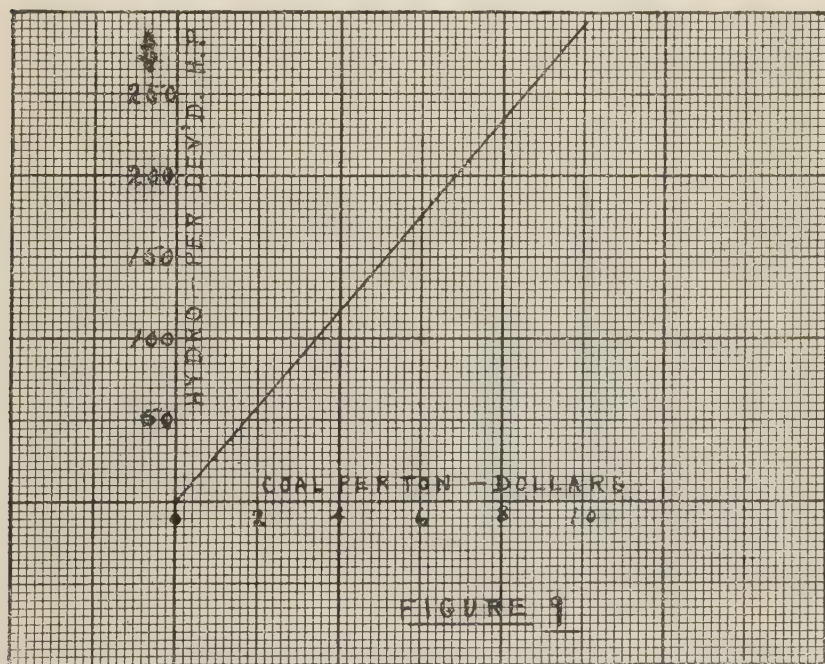


FIG. 9

somewhat lower level than that assumed for my estimate, nevertheless the Hopewell plant should be a commercial one, even if the cost of the dams works out more than double my estimate. The other items of the estimates can be and have been taken direct from the data on standard fresh-water developments, and should therefore be approximately right, as given above.

If the Maritime Provinces were blessed with great fresh-water powers, such as exist in Quebec and Ontario, the time might hardly be ripe for the development of this tidal plant, but, to quote from the Commission of Conservation's book (1911), it says, in speaking of New Brunswick, "The larger rivers for the most part are long and their fall is gradual;" and again, "There are comparatively few

lakes in the upper portions of the watersheds of the majority of the rivers, and hence little facility is afforded for the natural storage of waters for the purpose of equalizing the flow during the low-water periods." To emphasize this point I refer to the diagram, Figure 10, which shows the comparative power available at Hopewell, all fresh-water powers in New Brunswick, Grand Falls (the largest single fresh-water power), and Musquash (the first public development in the Province)—these are all on a 24-hour basis.

Nova Scotia is similarly placed as regards fresh-water powers, and the total estimate for the Province is only 128,000 horsepower; there-

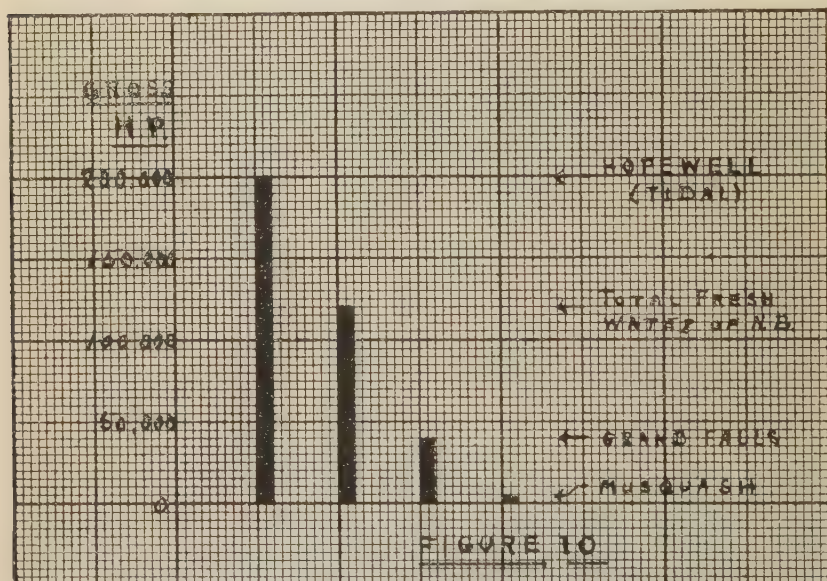


FIG. 10

fore the single plant at Hopewell would be almost equal to the combined fresh-water powers of the two Provinces.

Were we able to harness the power that is daily wasted in the two great eastern arms of the Bay of Fundy we could have the use of 3,500,000 horsepower, but this is a dream for the future and is not a practical proposition for to-day. The theory of the thing is the same as for the Hopewell plant, but the execution and cost would be impossible at present.

The Hopewell plant is to-day a good commercial proposition. Special engineering problems are attached to it, but they are only those that attach to any special plant. The difficulties are small in comparison to many recent engineering works that have been successfully carried out, and I trust that the near future will see this great plant in daily operation.



MISS OLIVE EDIS, F. R. P. S.

SIR JAMES DEWAR, F. R. S., LL. D.

SIR JAMES DEWAR, F. R. S., LL. D.¹

By SIR JAMES CRICHTON-BROWNE, M. D., LL. D., F. R. S.

[With 1 plate]

A great man of science has passed away, resolved into that atmosphere the secret of which he has done so much to disclose. Sir James Dewar died on March 27 at the Royal Institution in Albemarle Street, which has been for 46 years the scene of his labors; and his remains were, by his express wish, cremated at Golder's Green on the following Saturday.

Born at Kincardine-on-Forth under the shadow of the Ochill Hills, and near Stirling with all its romantic historical associations, on September 20, 1842, Sir James Dewar was reared in a Presbyterian home and was early introduced to the austere theology in the Shorter Catechism. In his tenth year there occurred an incident which probably colored his life. While skating on a winter's day he fell through the ice, and when rescued walked about in his wet clothes till they were dry, so that his family might not learn of his misadventure. The result of that was that he had a severe attack of rheumatic fever, which crippled him for two years and left him with a damaged heart. The heart trouble incapacitated him for the active life to which he had been previously disposed and permanently cut him off from strenuous games and exercises, but in no degree impaired his constitutional energy, which remained intact and unsurpassable till his death. It was in these two years when he was laid aside, free from schooling, with only a modicum of private tuition and cut off from the companionship of other boys of his age, that his native gifts had a favorable opportunity of spontaneous growth. He browsed unconfined on the wholesome pastures of English and Scottish literature, drank deeply of Burns, and above all, began to think for himself and to create; and creation is the essence of all genius. Always devoted to music, he had before his illness attained to some degree of proficiency on the flute, but was now debarred from that instrument by breathlessness, and so turned to the violin. With the help of the village joiner he made for himself several violins, one of which, wonderfully expressive in its tones, was played on at the celebration of his golden wedding in 1921.

¹ Reprinted, by permission, from *Science Progress*, July, 1923.

When 12 years old Dewar, still a pale and delicate boy, went to the Dollar Academy, a Scottish secondary school of high repute, of which he always spoke very gratefully, and there he resumed the ordinary routine of the education of the period. It was a little incident at Dollar, the discovery in the garden of Mr. Lindsay, the master with whom he was boarded, of an old and half-buried sundial, in the erection and orientation of which he took some part, that inoculated him with a taste for exact science; but it was not until he went to the University of Edinburgh, at the age of 17, that his apprenticeship to science really began. There he soon diverged from the accustomed literary course and plunged, as it were instinctively, into mathematics, physics, and chemistry. In this congenial element his ability was speedily recognized by two of his professors, Guthrie Tait and Lyon Playfair, the latter of whom made him his class assistant. There was great intellectual activity in Edinburgh while Dewar's lot was cast there in the sixties of last century, and into that he entered with zest and with an acceptance not usually accorded to so young a man. His teaching power attracted large classes to his practical demonstrations, and the experimental tendencies, which were in the marrow of his bones, unmistakably displayed themselves, leading Lyon Playfair to suggest to him that he should accept an appointment for technical work in connection with the dyeing industry with which his friend Crum Brown, who became Playfair's successor, was, by family ties, associated. Had Dewar adopted this course Perkins might have been anticipated, but he preferred to remain in Edinburgh to carry on his less circumscribed researches there, in the meantime, however, enlarging the scope of his studies by a sojourn at Ghent, where under Kekuli he gave special attention to organic chemistry.

Returning to Edinburgh as demonstrator of chemistry in the university, he engaged, with Guthrie Tait, in experiments with Crookes's newly invented radiometer, and with McKendrick in an inquiry on the physiological action of light. From the university he passed to the Dick Veterinary College as professor of chemistry, and it was while diligently working there that an offer of promotion unexpectedly came to him. There was a vacancy in the Jacksonian professorship at Cambridge, for which there were several candidates, and a selection was imminent, but at this moment the late Sir George Humphrey visited Edinburgh as an examiner in the medical faculty and was introduced to Dewar. With keen discernment he took his measure and immediately telegraphed to Doctor Porter, then tutor, afterwards master of Peterhouse, "Hold your hand, I have found the man." At the same time Guthrie Tait wrote to Cambridge indicating Dewar, and that settled the matter, and the post was of-

ferred to him by telegram. He was busy and happy, a brilliant career in Edinburgh, almost inevitably culminating in a professorship, was opening out before him; but his young wife, with sure intuition, felt that he deserved a wider field than Scotland could afford, and so the die was cast, and the migration to Cambridge took place.

It would not be correct to say that Dewar found himself in a congenial element in Cambridge at that time. His lectures were an unprecedented success; he made some lifelong friends, of whom one, Professor Liveing, much loved and venerated, still happily survives, but some bristles of the Scottish thistle adhered to him, and chemistry and physics had not then come to their own on the banks of the Cam. He had not even such facilities as he had enjoyed in the north. His laboratory was a small room, without a fireplace and badly lighted; apparatus was conspicuous by its absence; and his aspirations, very forcibly expressed, were not very sympathetically received. It was, therefore, with satisfaction that he found himself translated to a more elastic atmosphere when in 1877 he was elected Fullerian professor of chemistry at the Royal Institution in succession to Dr. John Hall Gladstone.

It was in the laboratories of the Royal Institution during his incumbency of the Fullerian professorship that all Dewar's triumphs were achieved, more especially those in connection with the liquefaction of gases and the properties of matter at temperatures approaching the absolute zero. Faraday, the god of his idolatry in all scientific affairs, had led the way in this exploration and had by means of low temperature and pressure succeeded in liquefying all the then known gases except nitrogen, oxygen, and hydrogen, and the compound gases—carbonic oxide, marsh gas, and nitric oxide—and as early as 1874 Dewar was fascinated by the subject, as evidenced by his lecture before the British Association on "Latent heat of liquid gases." In 1878 he showed Cailletet's apparatus in operation in England. It was, however, the success of Wroblewski and Olszewski, of Cracow, in liquefying oxygen in 1884 that withdrew him from his earlier preoccupation, with the heat of the sun, electrophotometry, and the chemistry of the electric arc, and supplied the stimulus to his more memorable discoveries. In 1885 he was able to show a profoundly moved audience at the Royal Institution the air we breathe made visible as a clear liquid, compressed to one eight-hundredth of its bulk and produced at a temperature of -192° C. In 1893 came oxygen in a solid state, an ultramarine ice produced at -216° C., and in 1897 fluorine as a fluid. In the following year appeared liquid hydrogen, and in 1899, a crowning close of the century, that gas in a solid state at a temperature of -260° , or about 13° above the point of

absolute zero, that unplumbed depth where molecular movement is no more. Helium alone remained unsubjugated by Dewar, and that he would unquestionably have liquefied had not Onnes, of Leyden, working on his lines, accomplished the feat while he was preparing for it.

Now that liquid air is an article of commerce, Dewar's liquid-air work has become popular knowledge, but only an expert who has essayed such an enterprise can conceive the patience, the industry, the ingenuity, the constructive genius required in it. Dewar devoted to it years of unremitting toil and pursued it not without risk to life and limb, and sometimes embarrassed by the question of ways and means to carry on so costly a campaign. To obtain a degree of cold sufficient to liquefy hydrogen by means of internal work done by the molecules while a gas was being forced through a porous plug, involved the building up of a machine capable of sustaining pressure in many tons to the square inch, even at a temperature of -260° C., and fitted together with a nicety and precision of which even first-class engineering knows little. To protect the liquid gases when produced against the influx of heat, special measures were necessary, and the search for these led to the invention of the vacuum bulb, the parent of the thermo flask which Dewar's nimble brain devised, which must have brought him a huge fortune had he chosen to patent it, and which, if properly designated, should keep his name alive for ever, even amongst the masses of mankind. But the vacuum bulb, even when silvered, was not enough. In order to examine the liquefied gases in a static condition, and unevaporated for long periods, specially high vacua were needed, and these were procured by Dewar's utilization of the absorptive power of carbon. "The discovery of the marvelous power of charcoal to absorb gases at low temperature," says Professor Armstrong, "will render the period 1900 to 1907 ever memorable."

Dewar's liquefied gases, thus obtained, became themselves instruments of research, and enabled him to conduct novel and illuminative investigations on electrical conductivity, thermo-electric powers, magnetic properties, and electric constants of metals and other substances at low temperatures and on the effects of extreme cold on chemical and photographic action. Having established that chemical changes are almost quite inhibited at temperatures about 300° F. below zero, Dewar, with the assistance of Professor Macfadyen, determined to test how far vital processes were affected by the same conditions. A typical series of bacteria was employed for the purpose, possessing varying degrees of resistance to external agents. The bacteria were first simultaneously exposed to the temperature of liquid air for 24 hours. In no instance could any impairment of their vitality be detected in either growth or functional activity.

This was strikingly illustrated in the case of the phosphorescent organisms. Their cells emit light which is apparently produced by chemical processes of intracellular oxidation, and the phenomenon ceases with the cessation of their activity. These organisms, therefore, furnished a crucial test of the influence of low temperature on vital manifestations, and when cooled down in liquid air they immediately became nonluminous, but, on being thawed, the luminosity as speedily returned. In further experiments the organisms were subjected to the temperature of liquid air for seven days. The results were again nil, for on thawing they renewed their life processes with undiminished vigor. The organisms were next exposed to the temperature of liquid hydrogen—only 28° above the absolute zero—and again the results were nil. The fact that life can continue to exist at a temperature at which, according to our present conception, molecular action ceases and the entire range of chemical and physical activities, with which we are acquainted, either ceases or enters on an entirely new phase, affords ground for reflection, as to whether, after all, life is dependent for its continuance on chemical reactions.

Dewar's heroic attempts to reach the absolute zero of temperature, solving problems of supreme importance and intricacy by the way—time-and-strength-consuming though they were—did not exhaust his scientific energies or complete his conquests. As a member of the Explosives Commission in 1888, in conjunction with Sir Frederick Abel, he invented cordite, which became the standard smokeless powder, and during the war he contrived a light and portable apparatus for the conveyance of oxygen so that it might be available as a protection against mountain sickness for men going up in airplanes. He conjured up giant soap bubbles that survived for months, because the air inflating them was like Bonny Kilmenny, "as pure as pure can be," and spread out films of extreme tenuity that in their stream lines and vortex motion yielded to his manipulations, assemblages of dancing rainbows of exquisite beauty. He took part in many inquiries bearing on the public health and especially on the safeguarding and improvement of our water supply, and was a much sought and inexorable witness before committees of Lords and Commons. Along with Professor Liveing, he conducted an elaborate series of studies on spectroscopy that have now been collected in a volume, and would by themselves place him in the first rank as a man of science.

Besides doing his own work, Dewar was the cause of much work in others. He was eminently suggestive and freely helpful to all who sought his assistance. He did not suffer fools gladly, and was intolerant of pretentious mediocrity; but for the earnest student and

honest worker he had unfailing sympathy and encouragement. The fruits of his experience and the seeds of his speculations—and hypotheses of the right sort are valuable commodities in science—were always at the service of those who consulted him. And it is certain that ideas which he thus flashed forth have afterwards, without acknowledgment, materialized in profitable inventions.

Dewar identified himself with the Royal Institution and the Royal Institution became identified with him. He pervaded it so that many of its habitués entering it now feel as if the soul had gone out of it. The scene of his labors became the object of his affections, and he never spared himself in its service. Proud of its traditions, and conscious of the opportunities it had afforded him, he strove to enhance its reputation and extend its usefulness. He made liberal benefactions to its funds, and was wont to enlarge on the magnitude of its accomplishment with the very meager means at its disposal, pointing out that the fundamental ideas and experiments on which are based the stupendous chemical and electrical industries of to-day were worked out in its laboratories by Davy, Faraday, Tyndall, and himself at an average expenditure on research of £1,000 a year.

During his period of office at the Royal Institution Dewar delivered 238 lectures in all—49 Friday evening discourses, 48 Christmas lectures, and 151 afternoon lectures. As his lectures were no off-hand demonstrations, but carefully prepared expositions, every experiment being previously rehearsed, they entailed a heavy drain on his time and energy. In the 10 years—1884 to 1893—he delivered six of those Christmas courses of lectures to juveniles, which make peculiarly exacting demands on minute attention and lucid expression, dealing with subjects as varied as “Alchemy,” “Meteorites,” “The air,” “Clouds and cloudland,” “Frost and fire,” “Light and photography.” It was by the allurements held out by him that the late Dr. Ludwig Mond was induced to make to the Royal Institution the munificent gift of the Davy Faraday Research Laboratory, which affords unique opportunities to those individual and independent investigators on whom Dewar’s hopes for the advancement of science were mainly fixed.

Dewar had a singularly impressive and attractive personality. He had a head like Shakespeare, a countenance finely chiseled, expressive of vivid intellect and abounding vim blended with good humor. He gave the world “assurance of a man,” a strong true man, open hearted and open minded, quick of temper perhaps, but genial and generous withal, a staunch friend, a delightful companion. With a proper endowment of the *ingenium perfervidum Scotorum*, he was sturdy in spirit, intrepid in manner, fearless, patriotic, and given to hospitality. No one could be more inimical

than he to the occult in all its phases, and yet the press has been not altogether wrong in ascribing to him a certain wizardry—"the wizard of Albemarle Street" they have called him—for he was a wonder-worker and threw a spell over his audience. Bent on the pursuit of reality and on the control of nature through the advancement of knowledge, there was scope in the amplitude of his mind for ideal values. He had imagination, which is the forerunner of science, "the vision and the faculty divine," and was a connoisseur in music and the fine arts. On the bookshelves in his study, within reach from his easy chair, were assembled well-worn copies of the essays of Montaigne, Elia, and Emerson; the poems of Hardy, Walt Whitman, Rossetti, and Meredith; Landor's *Imaginary Conversations*; Carlyle's *Heroes*; *Sesame and Lilies*, and the *Cricket on the Hearth*.

Dewar was knighted in 1904, and that was the only and wholly inadequate recognition offered to him by his country, to which he brought honor and profit. But foreign countries and learned bodies were more appreciative of his merits than the dull-witted ministers at home. The royal and philosophical societies and academies of Rome, Belgium, New York, Philadelphia, Frankfort, Milan, and Copenhagen were proud to inscribe his name on their rolls, and all the four Scottish universities, as well as those of Oxford, Dublin, Brussels, and Christiania, conferred on him honorary degrees. The Royal Society awarded him its Copely, Rumford, and Davy medals, and he was president of the British Association in 1902.

Sir James Dewar married in 1871, Helen Rose, daughter of Mr. William Banks, of Edinburgh, and she survives him. Never had savant a more propitious spouse. Lady Dewar entered keenly into all her husband's interests, sustained him in his heavy tasks, and created the first scientific salon in London. There are few noted people in the world of science who have not attended the receptions in her drawing room at the Royal Institution after lectures there.



J. C. KAPTEYN

Photograph taken by F. Ellerman in 1919 during Kapteyn's last visit to Mount Wilson

J. C. KAPTEYN, 1851-1922 ¹

By A. VAN MAANEN

[With 1 plate]

In Amsterdam, on June 18, Jacobus Cornelius Kapteyn, since 1921 retired professor of astronomy and director of the astronomical laboratory at Groningen, died at the age of 71 years. In him astronomy loses one of its foremost pioneers.

Kapteyn was born January 19, 1851, at Barneveld, a small village where his father had a well-known boarding school. Of the 15 children of this family, several became leaders in the scientific world in Holland. From 1869 to 1875 Kapteyn was a student at the University of Utrecht, where his principal teachers were Buys Ballot and Grinwis, so that it is no wonder that his doctoral thesis was in physics: "*Onderzoek der Trillende Platte Vliezen.*" Just at this time, however, the position of observer at the Leiden Observatory was vacant, and Kapteyn applied for and obtained the position. By this accidental circumstance astronomy secured the privilege of counting Kapteyn as one of its workers and before long as one of its foremost leaders. His ability was soon recognized, and at the age of 27, which for Holland is extremely young, he was appointed full professor in astronomy at the University of Groningen. On entering office, February 20, 1878, his opening address had as subject: "The parallax of the fixed stars."

The problem of the stellar distances was naturally of first importance to him, whose ideal was to throw some light on the structure of the universe. We do not know when this idea began to ripen in Kapteyn's mind, but it probably dates from the time that he decided to devote his life to astronomy. And no better man could be found to push astronomy ahead along these lines, because Kapteyn had two qualities which were needed for such investigations: He could grasp a great problem and at the same time both could and was willing to devote much time to essential details. These two qualities show up through all his life, and we see him, never losing view of the greatest of astronomical problems, the structure of the universe, and at the same time working with painstaking assiduity to develop and improve the methods of securing the necessary data. Of this part of his work no better example can be given than the succession of new methods that he developed to obtain stellar distances. In 1882 the

¹ Reprinted, by permission, from the *Astrophysical Journal*, Vol. LVI, No. 3, October, 1922.

parallaxes of only 34 stars were known, the best results being due to heliometer observations, especially by Gill and Elkin at the Cape of Good Hope.

When Kapteyn came to Groningen his appointment was to the professorship in astronomy, calculus of probabilities, and theoretical mechanics, but he found no observatory at his disposal. Good mathematician as Kapteyn was, his heart was drawn more toward the practical side of his science, and during the first years in Groningen he tried hard to secure funds for an observatory, with a 6-inch heliometer as its principal instrument. In the beginning his efforts seemed to promise success, and ground for the observatory was bought a little outside of the city, but funds for the erection of the buildings were not forthcoming until many years later, by which time Kapteyn in his unique astronomical laboratory had founded an establishment which satisfied, better than an observatory could have done, the needs of this wonderful combination of the practical and the theoretical astronomer.

Lack of an opportunity for observational work was, however, keenly felt by Kapteyn during the early years of his professorship, and he requested Prof. H. G. van de Sande Bakhuyzen to let him use the meridian circle of the Leiden Observatory during his vacations. The request was granted and Kapteyn planned a careful program for the observation of stellar parallaxes; he introduced the differential method of observations in right ascension, thus deriving parallaxes for 15 stars, which in accuracy competed with those yielded by the heliometer, while the observations required less time. His thorough discussion of the method and of these observations in Volume VII of the *Annals of the Leiden Observatory* is one of the many contributions from his hand which will be recorded among the classics of astronomy.

But it was clear that for a solution of his great problem parallaxes must be determined more rapidly. In 1889, at the conference of the *Carte du Ciel*, Kapteyn outlined an ingenious scheme for measuring the parallaxes of a large number of stars by means of photography. The plan is extremely simple in theory: On the same plate three exposures are made at the epoch of maximum parallactic displacement; half a year later, at the minimum, six other exposures are made on the same plate, and three again at the following maximum; after development the plate shows 12 images of each star which in practice are arranged as follows:

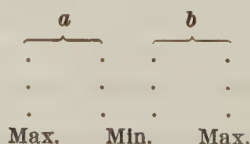


FIG. 1.—Arrangement of exposures for the determination of stellar parallaxes according to Kapteyn's plan

The distances a and b are then measured and reduced by a simple process; and yield, with respect to the mean parallax of all the stars measured, the parallax of every star visible on the plates. The method was put into practice by Kapteyn and Donner and the first results were published in 1900 as No. 1 of the Publications of the Astronomical Laboratory at Groningen, a remarkable series of publications which has contributed much to the development of astronomy in the last 20 years.

While similar results for different fields, mostly in collaboration with De Sitter, appear in the Groningen Publications, we soon perceive a change in his policy of attack on the general problem. The change from parallaxes to proper motion, however, is more apparent than real, and is founded on the practical fact that by using the proper motions we can base the parallaxes on the ever-increasing base line of the sun's motion through space, and on the theoretical fact that for the structure of the universe it is not at all necessary to know the distances of individual stars, but the mean distances of groups of stars for different magnitude, spectral type, and galactic latitude. The problem has two requirements: An accurate determination of the sun's motion through space and a knowledge of the distribution of proper motion for an increasingly great number of fainter and fainter stars. Along both lines the Groningen Publications reveal how much Kapteyn advanced our knowledge. And it is in just such work as this that Kapteyn's double aptitude for recognizing great problems and at the same time perceiving the practical difficulties was of the greatest usefulness. Kapteyn would work out a new method which, with the proper material, would give the desired results; but he would at the same time also apply his method to the material available, even when it was scanty and likely to yield only defective results. This, however, had the advantage of showing at once where the method itself could be improved and what data would be most needed. We see him follow this means of attack in all his problems, by successive steps coming ever closer to the laws governing the structure of the universe.

Incidentally, the investigations on proper motion led Kapteyn to his discovery of the two star streams, which, rightly, was recently selected by Eddington as one of the five greatest astronomical events of the last hundred years, a discovery which has revolutionized our ideas of the structure of the universe. In deriving the solar motion Kapteyn was struck by the divergency of the results of former investigators. In these researches it was usually assumed that the *motus peculiaris* of the stars was at random, a natural hypothesis, since with the enormous distances of the stars from one another it was difficult to see why there should be any relation between the individual motions of different stars. Yet stars moving

together in pairs or even in large groups were known. As early as 1896, however, Kapteyn had noticed that the distribution of motion was not at random, but it was not until 1904 that he showed that there is a fundamental peculiarity in these motions and that they are not moving even approximately in a haphazard way. Instead of moving in all directions, as a random distribution would require, the stars tend to move in two preferential directions. That this tendency was so long overlooked by those who were working on a determination of the solar motion is principally due to the fact that they used the mean motions of all the stars in certain parts of the sky. Kapteyn, however, went to work in a different way, plotting the proper motions for limited regions of the sky. If for convenience sake we assume all the stars in a certain region to be located in the same point S of the sphere, then with a random distribution of the *motus peculiaris* alone, we find about the same number and about the same total motion in each direction. A motion of the observer, such as we have as a result of the sun's motion through space, will add to each star a parallactic motion in the direction of the antapex. While this of course will disturb the symmetry of the motions around the point S, we still will have bilateral symmetry, the line of symmetry evidently passing through the point S and the apex. This evident condition of bilateral symmetry would probably furnish the best means of determining the apex, as these lines of symmetry for the different parts of the sky must all intersect in two points, the apex and the antapex. In applying this idea to the proper motions of about 2,400 Bradley stars, divided into 28 regions, Kapteyn derived the distribution of the proper motions corresponding to the center of the areas. The whole of the material was thus embodied in 28 figures, like those in Figure 2, each of which shows at a glance the distribution of the proper motions for one particular region of the sky. This figure 2 is the same as the one shown by Kapteyn at the Cape meeting of the British Association for the Advancement of Science in 1905. Not to overburden the plate, only 10 of the 28 regions are included. If the hypothesis of random distribution were true, all these figures should be symmetrical with respect to the line through the center of each field and the apex. It is clear that this is not the case; each figure shows two preferential deviations. Kapteyn showed that the assymetry as shown in the figure can be explained neither by an uncertainty in the precession, nor by systematic errors in the proper motions, nor by an erroneous position of the apex. As all the lines of favored directions for the two sets seem to converge, approximately, to two points, some 140° apart, the one 7° south of α Orionis, the other a few degrees south of η Sagittarii, Kapteyn came to the conclusion that we

must have to do with two star streams, parallel to the lines joining our solar system and the two points mentioned.

It is evident that such a discovery as that of the star streams would revolutionize the ideas of the structure of the universe. But at the same time it pointed out the necessity of collecting an increasing amount of data, in order to secure more reliable measures and especially data for the fainter stars. It was clear that the desire for such data could be satisfied only by the thorough cooperation of several institutions according to a well-organized plan. Kapteyn certainly was the right man to start such an organization. Through

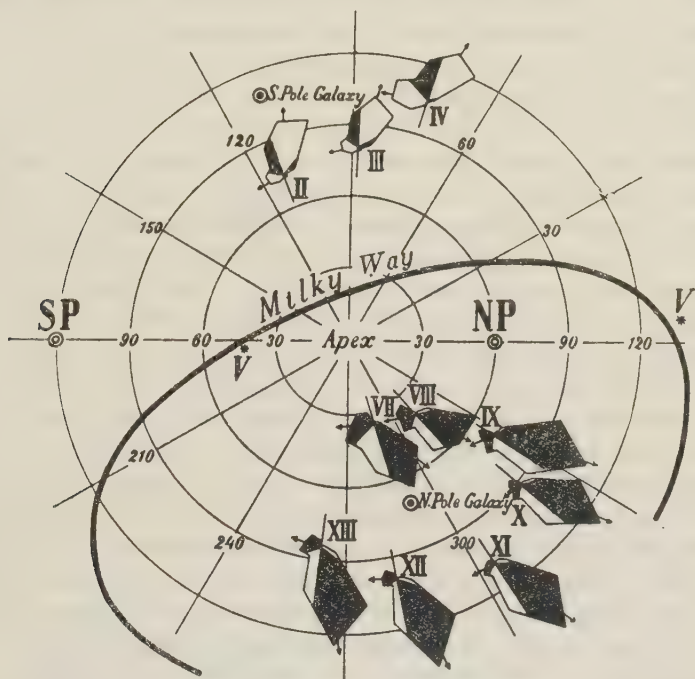


FIG. 2.—Distribution of proper motion in different parts of the sky which led to Kapteyn's discovery of the star streams

his work he had come into contact with most of the leading astronomers all over the world. His visits to America in 1904 and South Africa in 1905 gave splendid opportunity for discussing his plans with a number of eminent astronomers. In order to enable those who showed an interest in the matter to judge more thoroughly of the details, Kapteyn worked out a provisional plan; the result was a great deal of discussion and many useful suggestions. In 1906 Kapteyn published his famous Plan of Selected Areas. This pamphlet gives briefly but clearly, as only Kapteyn could give it, a program for the further attack on the structure of the universe. It includes not only the general plan but also in careful

detail the methods of securing the necessary data: Magnitude, proper motion, parallax, class of spectrum, and radial velocities for the stars in 252 well-selected regions. In the first and second reports (1911) Kapteyn was able to announce the formation of a committee to share the responsibility of advancing this plan. Its membership included Gill, Pickering, Hale, Küstner, Schwarzschild, Dyson, Adams, and Kapteyn, and it is sad to state that with Kapteyn one-half of its members have already gone forever. Yet the whole astronomical world is so convinced of the need of such a cooperative plan that it will undoubtedly be continued.

Next to the motions of the stars, their distribution in space interested Kapteyn most keenly. In this connection he derived the two well-known laws: The density law and the luminosity law, the former giving the density of stars per unit of volume and the change in the density with distance from the sun, and the latter, the percentage of stars equal in luminosity to the sun, and of those ten times, one hundred times, etc., as bright or as faint. Both are statistical laws; they do not give the distance and brightness of the individual stars, but how many stars there are at a certain distance and of a certain brightness. By successive steps these researches led Kapteyn to a conception of the distribution of the stars in space; they indicate that the stars are contained in a nearly ellipsoidal universe with an axial ratio of 5:1, with a decrease in the density away from the center and with the sun at a distance of about 650 parsecs from the center. In his last long paper on the subject, which with the modesty of the really great, was called "A first attempt at a theory of the arrangement and motion of the sidereal system," Kapteyn had the satisfaction of giving a beautiful exposition of his life work. If a longer life had been granted to him, undoubtedly we would have seen him elaborate his beloved subject; yet, as it is, it must have been a great satisfaction to him to reach this goal.

At about the time Kapteyn was spending his vacations in Leiden for the purpose of making his determinations of stellar parallaxes, he became acquainted and was soon on terms of warm friendship with the man who was then the leader in practical astronomy, David Gill, director of the observatory at the Cape of Good Hope. The story of the Cape Photographic Durchmusterung is well known to every astronomer. The difficulties met by Gill and Kapteyn would have disheartened most men. Kapteyn's famous letter of 1886 to Gill, offering his help in the following words, "However, I think my enthusiasm for the matter will be equal to (say) six or seven years of such work" has been widely quoted. It took about double that time, yet his enthusiasm did not fail, and the Cape Photographic Durchmusterung was completed with a thor-

oughness and accuracy which could be obtained only by two such masters. If we had no other work from his hand, Kapteyn's name would still take an honorable place in astronomical literature and would be mentioned with those of Argelander, Schönfeld, and Gould, names which every astronomer honors with gratitude. Yet in addition to this we have his discovery of the star streams, his plan of selected areas, his founding of the Groningen Astronomical Laboratory, now called "Astronomical Laboratory Kapteyn," which at the recent meeting of the International Astronomical Union, Baillaud duly called one of the three things which in his 50 years of astronomical life had revolutionized his science; and above all we have Kapteyn's investigations on the structure of the universe.

Truly Kapteyn belonged among the few really great men whose death creates a vacancy which can not be filled.

It seems superficial to enumerate here the many honors bestowed on him during his life. For completeness, however, we must mention them: Kapteyn received the honorary degree of D. Sc. from the Cape of Good Hope; of D. Sc. from Harvard University; of LL. D. from Edinburgh; he received the gold medal of the Royal Astronomical Society, the Watson and the Bruce medals and the Prix de Pontécoulant; he was chevalier of the Legion of Honor of France, of the Netherlands Lion; he had the order "Pour le Mérite," and was commander in the Dutch order of Oranje-Nassau. Kapteyn was elected a member or associate of the following academies: Royal Astronomical Society, American Philosophical Society, National Academy of Sciences, Imperial Academy of St. Petersburg, Royal Academy of Dublin, Royal Academy of Edinburgh, British Association, Royal Swedish Academy, Royal Society of Sciences of Upsala, American Society, the Academy of Sciences in Paris, the Royal Society of London, the Academy of Sciences in Finland, and of the Royal Physical Association in Lund.

All through his life Kapteyn made friends—when he was young, among the older people; when older, among each new generation with which he came in contact. It was not difficult to become his friend; he saw always the best qualities in every person; the rest did not exist for him. There was always an atmosphere of happiness around him, in his daily life as well as in the scientific assemblies, where he was the center of gravity. His departure will be keenly felt in the astronomical world, but not there alone; many others will mourn the ending of this noble and happy life.

Especially in America, Kapteyn had numerous friends. From 1908 to 1914 he came to this country every summer to spend a few months at the Mount Wilson Observatory, of which institution he was research associate. Kapteyn and Mrs. Kapteyn thoroughly

enjoyed their American trips, and these visits were no less appreciated by all with whom they came in contact.

Mrs. Kapteyn was born Catharina Elisabeth Kalshoven, and they were married in 1879. Their married life was singularly happy, and she has been devoted to the welfare of her husband and children—two daughters and a son—Jacoba Cornelia, wife of Prof. W. Noordenbos, of Amsterdam; Henriette, wife of Prof. E. Hertzsprung, of Leiden; and Gerrit Jacobus Kapteyn, who is a mining engineer.

How truly are his characteristics described by his friend Huizinga in the July number of the *Gids*: "When the right biographer for Kapteyn is found the 'Life of Kapteyn' will be one of the most beautiful books that can be written."

JULIUS VON HANN¹

By G. C. SIMPSON

It is probably the lot of everyone to have had during life a regard for some person which amounts almost to personal and intimate friendship, although one may never have seen or even corresponded with the object of that regard. Sometimes it is an author, sometimes a character in a book, and sometimes a historical personage, but in every case the feeling is very real and vivid. The scientist experiences this feeling quite as strongly as those of a more literary turn of mind, and to many of us Faraday, Maxwell, Kelvin are not mere names met with in textbooks, but real live men worthy of honor and devotion.

To many meteorologists, certainly to all who can read German, Julius von Hann appealed in this way. One knew from his writings, seldom controversial, never militant, that he must be of a quiet retiring nature, a conclusion confirmed by all those who have had the pleasure of his acquaintance. One likes to picture him in his room in the Hohe Warte in Vienna searching, always searching, in likely, and more often in unlikely, places for any reference to weather conditions which could add to our knowledge of the atmosphere and its ways.

And when Hann had once found a piece of weather information it could never again be lost to the world. Within a month or two of its discovery it was made known to all those whom it might concern in the pages of the *Meteorologische Zeitschrift*; but that was not all, for Hann's encyclopædic mind was able to see its relationship to other factors, and like a piece in a puzzle it was fitted into its place to make possible those masterly descriptions of climate found in his *Klimatologie* and those clear accounts of atmospheric processes which make up his *Meteorologie*.

Hann started his life as a school-teacher, but at the age of 29 his natural love of meteorology led him to enter the Central-Anstalt für

¹ Reprinted from the *Meteorological Magazine*, Vol. 56, No. 670, November, 1921, by permission of the controller of H. M. Stationery Office, London.

Meteorologie in Vienna; six years later, in 1874, he became director and held that office until 1897, when at the age of 58 he retired. His retirement was only from official duties; from meteorology he could not retire until the very presence of death made further work impossible. The first fruit of his relief from official duties was his *Lehrbuch der Meteorologie*, which was written between the autumn of 1898 and August, 1900, in the Physikalische Institut in Graz. This book, which was so different from any previous textbook of meteorology, became at once the recognized standard book of reference, and from 1900 onwards practically no major piece of meteorological work has been published which does not draw upon the *Lehrbuch* for facts and data.

Hann's *Handbuch der Klimatologie*, which had been written while he was still director of the Central-Anstalt, is probably better known to British meteorologists than the *Lehrbuch*, for the only reason that it has been published in an English translation. It is surprising how readable Hann has made this book, dealing, as it does, with little more than a mass of climatological statistics collected from all parts of the world. But that is one of the great charms of Hann's writing, that he is able to present the driest of meteorological facts in a pleasing and enticing manner. In the *Klimatologie* this end has been reached by leaving in so much of the original work from which the information has been extracted. It helps even a meteorologist to enjoy the account of the climate of a place if he knows that the data were provided by a Livingstone, a Franklin, or a Scott.

The *Klimatologie* and the *Meteorologie* are Hann's largest individual works, but it is questionable whether the writing of these books is his most valuable contribution to meteorology. Probably science owes more to him for the mass of information he has rescued from oblivion and preserved in the *Meteorologische Zeitschrift*, of which he was the editor, or joint editor, from 1866 to 1920, the *Zeitschrift* in the meantime undergoing several changes both in name and control.

Hann has received many honors, national and international; probably of all of these, those which he most appreciated were the issue in 1906 of a special volume of the *Zeitschrift* called the Hann Band, to celebrate his 40 years of editorship, and the spontaneous exhibition of esteem which he received on his eightieth birthday from all parts of the world in spite of the disastrous effects of the war on international relationships.

Hann was born on March 23, 1839, and died on October 1, 1921—a long life, a full life, and a life for which every meteorologist has cause to be grateful.

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